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Tennessee Valley Authority
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EPA
United States Environmental Protection Agency
Industrial Environmental Research Laboratory
Cincinnati OH 45268

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October 1979

Research and Development

Ecological Recovery After Reclamation of Toxic Spoils Left by Coal Surface Mining

Phase I

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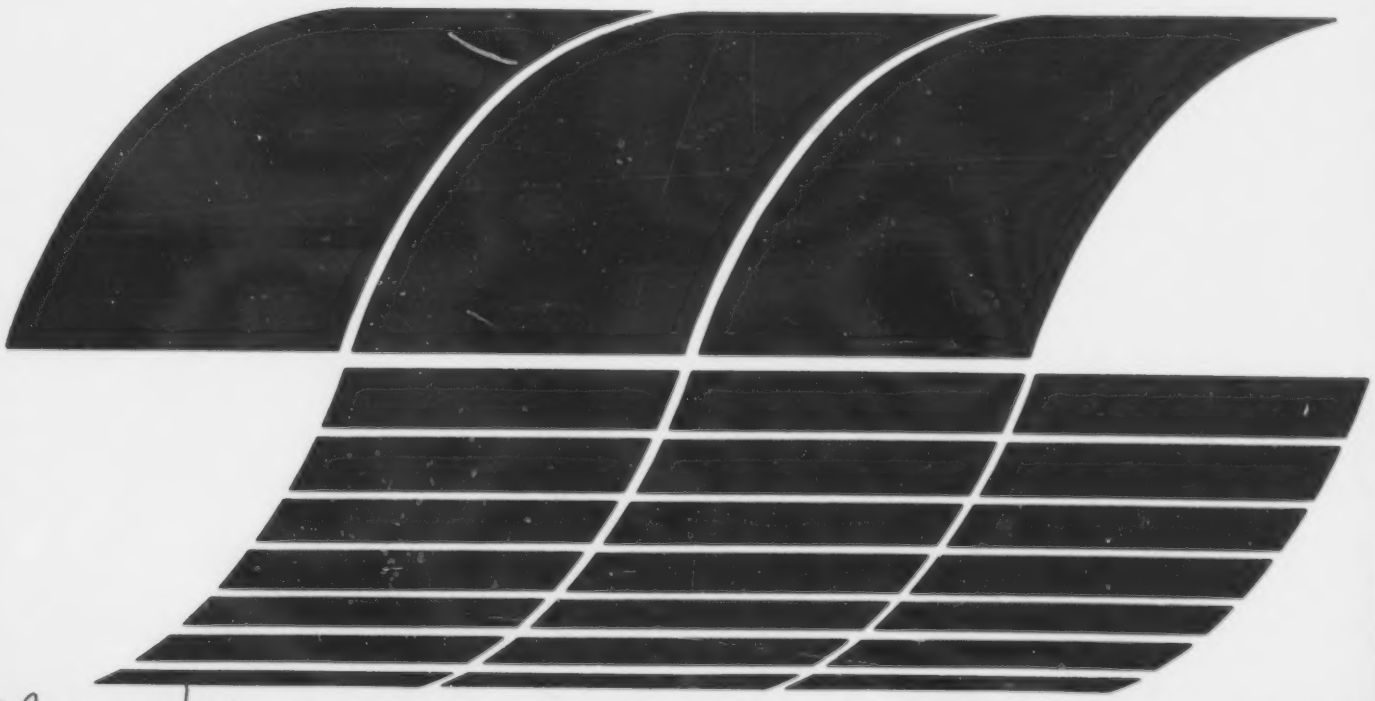

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October 1979

ECOLOGICAL RECOVERY AFTER RECLAMATION OF TOXIC SPOILS LEFT BY COAL SURFACE MINING

Phase I

A Baseline Assessment of Environmental Conditions Prior to Application of Intensive Remedial Treatments

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FOREWORD

When energy and material resources are extracted, processed, converted, and used, the related pollution impacts on our environment and even on our health often require that new and increasingly more efficient pollution control methods be used. The Industrial Environmental Research Laboratory-Cincinnati (IERL-Ci) assists in developing needs both efficiently and economically.

Reported here are the results of a study conducted as part of the Federal Interagency Environment Research and Development Program. This report documents the terrestrial and aquatic ecosystems of a coal surface mine in Tennessee prior to reclamation. It will be followed by a second report documenting the recovery after restorative treatments. The results of this work should be of interest to the biologist, engineer, etc., who is planning a reclamation project or evaluating the damages from surface mining. For further information contact the Extraction Technology Branch of the Resource Extraction and Handling Division.

David G. Stephan
Director
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ABSTRACT

This study involves a selected watershed in which surface mining and unsuccessful reclamation efforts in the early 1970's resulted in adverse environmental impacts. Work on the east Tennessee problem mine seeks to correct reclamation deficiencies by applying land stabilization treatments and evaluating their effectiveness by measuring the degree of recovery of the affected terrestrial and aquatic ecosystems. Conditions documented during the mining and reclamation, and those existing prior to start of restorative treatments, are recorded to serve as baseline for measuring ecological recovery. Progress on treatment implementation is reported through the 1977-1978 planting season. Evaluations on environmental effects cover the period from start of mining to July 1976.

This report was submitted by the Tennessee Valley Authority, Division of Land and Forest Resources, in partial fulfillment of Energy Accomplishment Plan No. 80 BDQ under terms of Interagency Agreement No. D8 E721-DQ with the Environmental Protection Agency. Work was accomplished as of July 6, 1978.

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SECTION 1

INTRODUCTION

The purpose of this investigation is to determine the rate of recovery of a damaged ecosystem in response to intensive remedial treatment of a problem surface mine. This study involves a forested watershed in which 162 hectares (ha) (400 acres, ac) were disturbed by coal surface mining in the early 1970's. Unsuccessful reclamation efforts resulted in adverse environmental impacts within the 28 square kilometer (sq. km) (11 square mile, sq. mi) watershed that includes a city water supply reservoir.

An evaluation of the mine site in spring 1974 showed only 24 percent of the land surface stabilized and led to development and implementation of an intensive remedial land treatment plan. Major study emphasis is on documenting the general mined land and stream quality conditions resulting from the problems created by mining and determining the rate of recovery of terrestrial and aquatic life after selected reclamation.

This report describes (1) the project area and impacts resulting from the coal surface mining, (2) efforts by the mine operator to reclaim the land by conventional measures, (3) tests and evaluation leading to development of an intensive land treatment, and (4) baseline terrestrial and aquatic ecosystem conditions. Biotic and water quality data collected in the first few months into the treatment phase are included to further establish environmental baseline.

A later report will document the changes in terrestrial and aquatic ecosystems and water quality as a result of the remedial land treatment.

SECTION 2

THE PROJECT AREA

LOCATION AND DESCRIPTION

The study area, Ollis Creek watershed, is located on land owned by Koppers Company, Inc., 8 kilometers (km) (5 miles, mi) north of Caryville and just east of Interstate 75 in Campbell County, Tennessee. Access is from Exit 33 by a gravel, coal haul, and logging road serving the property. Configuration of this mined area and its proximity to LaFollette, Tennessee, is shown in Figure 1.

Ollis Creek drains into a reservoir behind a concrete dam constructed in 1964 by the city of LaFollette. Storage water is released from this reservoir (Reservoir No. 2) to a smaller downstream impoundment (Reservoir No. 1) from which the city draws its needs. Upstream from the concrete dam the watershed drainage is 28 sq. km (11 sq. mi). This includes drainage from several small Ollis Creek tributaries which enter directly into the reservoir. Watershed elevations range from 415 meters (m) (1,360 feet, ft) at the spillway crest to 762 m (2,500 ft) in the upper extremes.

The watershed is heavily forested with oak-hickory, the predominant forest type. White and red oaks and hickory comprise the major hardwood sawtimber species, mostly in tree quality grades 2, 3, and structural. Other types present in the forest include yellow-poplar and Virginia pine. While logging has been active for many years, the forest is still relatively well stocked. Previous surface mining disturbed approximately 49 ha (120 ac). Most of this orphan land remains barren because of acid spoil conditions. There is also evidence of old deep mines along the main Ollis Creek drainage and on Thompson Creek, arm of Ollis Creek.

The Ollis Creek area is bordered on the south by the Cumberland escarpment. Soils in the watershed are of either the Ramsey-Jefferson-Hartselle association or the Muskengum-Jefferson-Barbourville association, depending on the amount of clay, sand, and silt present (1). The major soil type may be Muskengum stony fine sandy loam, steep to hilly phase, or Lehew fine sandy loam, steep to hilly phase. The majority of the area in the Ollis Creek watershed is underlain by the Slatestone group and may occur in conjunction with acid sandstones from the Crab Orchard and Gizzard groups (2).

Area weather station records show annual precipitation for the years 1970 through 1974 to average 132 centimeters (cm) (52 inches, in.). At the LaFollette Water Treatment Plant, Station 325a, on Ollis Creek, the normal yearly total precipitation is 127 cm (50 in.) to 140 cm (55 in.). Yearly

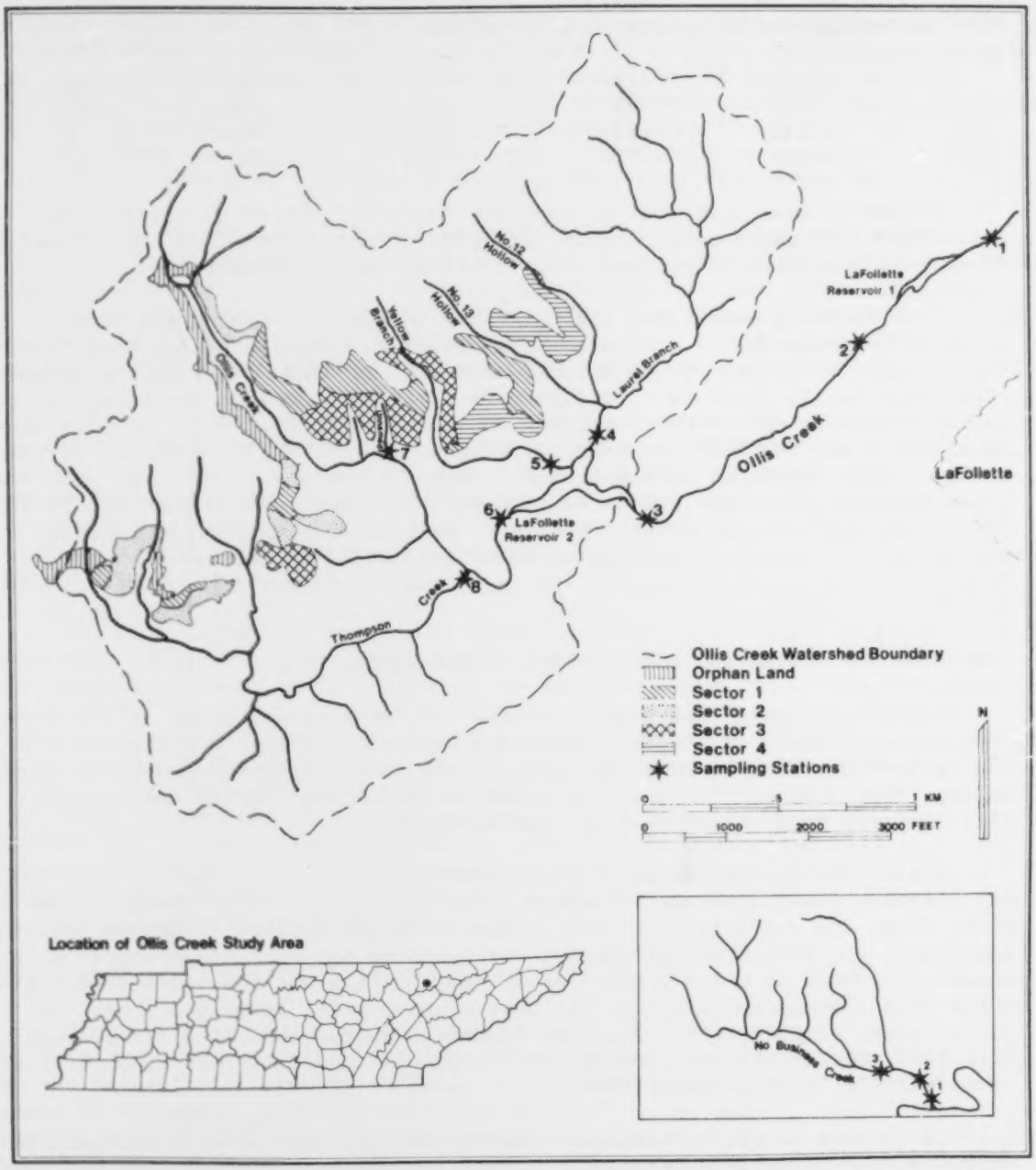

Figure 1. Ollis Creek Watershed with inset of No Business Creek Watershed and in-State location.

precipitation at the water plant exceeded these totals in most years from 1970, when stripping began, through 1975.

Individual yearly totals were as follow:

	cm	in.		cm	in.
1970	142	56	1973	193	76
1971	135	53	1974	165	65
1972	180	71	1975	157	62

Estimated mass inflow at Ollis Creek Reservoir, based on actual flow measurements of gaged area streams with similar characteristics, is estimated at over 11.4 million kiloliters (kl) (3 billion gallons) annually.

Coal reserves underlying the watershed include the Coal Creek seam. Luther (3) identifies it as the most important in Campbell County both from the standpoint of past production and reserves and also, one with the largest known recoverable reserves of any seam in Claiborne County. The Keystone Coal Industry Manual (4) further describes the seam: "The Coal Creek seam is mined in Anderson and Campbell Counties but is too thin for exploitation in Morgan County. Seam thickness ranges from 102 cm to 152 cm (40 to 60 in.), with most seams between 102 cm and 122 cm (40 and 48 in.) thick. Where the seam is 107 cm (42 in.) or more, it usually carries a parting varying from knife-edge thickness to 10 cm (4 in.) slightly below the middle of the bed." The Slatestone overburden is usually low in pH and fertility, and averages 18-21 m (60-70 ft) thick.

CHRONOLOGY OF MINING AND CONVENTIONAL RECLAMATION

Surface mining of the Coal Creek and Coal Creek Rider seams in the watershed began in April 1970 under a contract awarded by TVA to a private operator. TVA reclamation requirements (Appendix A) and State regulations applied to the mining. Some 162 ha (400 ac) were mined in recovering 542,767 metric tons (mt) (598,298 tons, t) of coal through April 1972.

Mining during the two years progressed generally along the 549 m (1,800 ft) contour from points near Thompson Creek and east of Ollis Creek. From Ollis Creek the operator continued to Number Twelve Hollow. Then the operator moved back to Ollis Creek proceeding northward on the east slope and to points immediately west of Ollis Creek. After that, mining was resumed in the Flatwoods area (Thompson Creek) and the northernmost point immediately east of Ollis Creek. Eighteen ha (45 ac) of land were disturbed from April through June 1970, 94 ha (233 ac) from July 1970 through June 1971, and 51 ha (127 ac) from July 1971 through April 1972.

An account of reclamation performed by the operator is detailed here to emphasize the repeated revegetation efforts. Hydraulic seeding equipment was used in applying seed, fertilizer, and mulch. Tree planting was by hand labor using planting bars. To minimize stream siltation, 41 silt-control structures were constructed within the watershed from May 1970 through November 1974 (Appendix B).

By October 1970 approximately 34 ha (85 ac) were seeded with perennial ryegrass, Kentucky-31 fescue, and annual ryegrass at 17, 17, and 11 kilograms/hectare (kg/ha) (15, 15, and 10 pound/acres, lb/ac), respectively. The same area was fertilized with 6-12-12 at 448 kg/ha (400 lb/ac) and ammonium nitrate at 112 kg/ha (100 lb/ac) and mulched with wood fiber at the rate of 1,680 kg/ha (1,500 lb/ac). About 78 ha (193 ac) were seeded, fertilized, and mulched during the spring of 1971. During late winter and early spring 1970-71, 135,000 black locust and 8,000 loblolly pine seedlings were planted on 61 ha (150 ac) of outslope. (Initially no trees were required on the bench area.)

During winter 1971-72 approximately 75,000 black locust were planted on 31 ha (77 ac). During spring 1972, 72 ha (178 ac) were seeded with Kentucky-31 fescue and annual ryegrass at 28 kg/ha (25 lb/ac) each and fertilized with 6-12-12 at the rate of 168 kg/ha (150 lb/ac). This hydraulic seeding included at least 16 ha (40 ac) of previously seeded surface. Failure to establish a suitable cover was attributed to acidity of the surface spoils.

Pyrites in the overburden were left on the surface during the grading operation. This material formed sulfuric acid upon oxidation and hydrolysis, causing the pH of the spoils to drop. Spoil samples collected as early as September 1970 on the first point beyond Ollis Creek showed pH values to average 4.6. Samples from the head of Thompson Creek ranged from 3.9 to 4.7. In December 1970 eight pH samples taken on the second point beyond Ollis Creek ranged from 3.0 to 4.7.

Another attempt to revegetate these areas was made by the operator in September 1972. Recognizing the spoil problem, other acid-tolerant species and fertilizers were used: bench areas--Kobe lespedeza and Korean lespedeza at 28 kg/ha (25 lb/ac) each and 0-46-0 and 33-0-0 at 112 kg/ha (100 lb/ac) each; outslope--weeping lovegrass at 8 kg/ha (7 lb/ac) and 0-46-0 and 33-0-0 at 112 kg/ha (100 lb/ac) each. Thereafter, all areas were reseeded with the above mixture through spring 1973. Additionally, 300,000 black locust seedlings were planted on bare outslopes and 40.5 ha (100 ac) of bench. Another 100,000 black locust seedlings were planted during the 1973-74 planting season. These repeated seeding and planting efforts helped in establishing additional vegetation, but overall, the cover was inadequate to provide needed offsite protection.

STRIP MINE REVEGETATION TESTS AND DEMONSTRATIONS

During the period of mining and conventional reclamation, a number of tests and demonstration projects were conducted on the mine seeking solutions to the revegetation problem (Appendix C). These included tests on wildlife plant pH tolerance, mulching materials and soil conditioners, use of lime and topsoil as site modifiers, and documentation of changes in soil acidity brought by weathering and use of spoil amendments. Demonstration activities involved revegetation with municipal compost, grass and legume seeding, and planting wildlife shrub species for habitat improvement.

The wildlife habitat improvement demonstration was initiated during the spring of 1971 with the planting of 25,000 wildlife food and cover plants. An additional 7,500 were planted in 1972 and over 6,800 added in 1973. The improvement of existing habitat structure and enlargement of the food base available to wildlife were primary objectives. A 1973 report (5) compares 1971 and 1972 planting results and subjectively evaluates wildlife usage and native plant invasion. Five species of wildlife shrubs proved tolerant to acid conditions of the Ollis Creek spoils. They were autumn olive, shrub lespedeza, crabapple, European alder, and sawtooth oak.

These and other test results were used as a guide in developing remedial land treatments. The approach followed a pattern outlined by Vogel (6) suggesting: ". . .future revegetation research on surface-mined lands should be concerned with establishing vegetation to minimize damage to the water resource. . . These lands must be compatible with watershed protection." This has been a main consideration in the search to find a remedy for the specific Ollis Creek mine problem.

MINING IMPACTS

The mining and unsuccessful reclamation resulted in adverse environmental impacts within the watershed--those expected to occur to a limited extent during active mining and those unexpected which resulted from revegetation failures. These impacts occurred despite upgrading of contract reclamation provisions for mining on the property and extra effort by the operator to revegetate the site. Monitoring was initiated at the onset of mining to record operational effects on receiving stream fauna, water quality, and sediment deposition in the city water supply reservoir.

Mining coincided with several years of above normal rainfall. Precipitation at the LaFollette Water Treatment Plant, Station 325a (1970-1975), averaged 162 cm (64 in.) annually, 30 cm (12 in.) above normal. It exceeded the norm in 1972 by 41 cm (16 in.), in 1973 by 61 cm (24 in.), and in 1974, by 33 cm (13 in.).

Terrestrial

A spring 1974 survey and problem analysis (7) showed only 24 percent of the mine surface had been revegetated. Phytotoxic spoils covered almost all the remaining acreage. Steep outslopes were barren and erosion from these, as well as bench areas, was contributing seriously to offsite damage. Equally serious was the nonproductive state of the mined land area.

Aquatic

Monitoring of physical and chemical water quality on the Ollis Creek drainage was first initiated in August 1970 and continued through October 1972 (8). Biological surveillance began in June 1970 and continued through October 1972 (9). During these periods there was a general deterioration of receiving stream quality. Stations upstream from the upper reservoir were subject to runoff water laden with silt--from both strip mine spoils and the many logging

trails in the watershed. Retention dams constructed below the mining were effective in relieving sediment problems at most stations. Some, of course, filled and additional dams were built. However, water pH and turbidity became stream stress factors which affected maintenance of a balanced aquatic fauna. Stream conditions during mining and conventional reclamation are discussed further under Aquatic Systems (Section 5).

Reservoir Sedimentation

Data on deposition of sediment in the downstream water supply reservoir (Reservoir No. 2, Figure 1) were collected annually beginning in October 1970. Sediment began to show up in October 1972 measurements. Rate of deposition and its impact on water storage capacity are reported under Reservoir Sedimentation (Section 6).

SECTION 3

REMEDIAL TREATMENT

Due to the serious problem of bare acid spoils and because it was unrealistic to request additional revegetation work from the operator, TVA, in fall 1974, assumed responsibility for needed remedial work. Many possible remedies were evaluated. These included various combinations of treatments that considered some regrading and even topsoiling of the most critical sites. Selection of treatments that would effectively stabilize the surface without accelerating the rate of reservoir siltation was a major concern.

The spring 1974 evaluation (7) showed some 39 ha (97 ac) to have adequate vegetative cover. The solution chosen to revegetate the remaining 125 ha (308 ac), relied heavily on results from a lime and topsoil study (10). Treatments selected and initiated on 40.5 ha (100 ac) during the fall of 1974 included liming and disking agricultural limestone to raise spoil pH, seeding with grasses and legumes to provide a protective ground cover, and planting trees and shrubs the following planting season.

Specifically, cultural practices to establish herbaceous ground cover consisted of both fall and spring treatments. Fall treatments involved liming at the rate of 22.4 t/ha (10 t/ac) and disking; fertilizing with a 6-12-12 fertilizer at 224 kg/ha (200 lb/ac); and seeding a mixture of half rye, or barley, and half Kentucky-31 fescue at 67 kg/ha (60 lb/ac). In the following spring the same area was overseeded with a mixture of Kentucky-31 fescue, sericea lespedeza, and weeping lovegrass at 34, 34, and 2 kg/ha (30, 30, and 2 lb/ac), respectively. Additionally, a 6-12-12 fertilizer was broadcast at 224 kg/ha (200 lb/ac).

Remedial work was planned so as to complete vegetation establishment over a three-year period by treating approximately one-third of the 125 ha (308 ac) each year. Within certain economic constraints, this was considered the most effective way to remedy the problem and minimize damage to the water resource.

LAND SECTORS AND TREATMENT

The mine was divided into four sectors (see Figure 1)of approximately equal land area--a control (Sector 1) with adequate vegetation and three sectors (Sectors 2, 3, and 4) comprising the poorly revegetated problem sites.

Sector 1 contains 39 ha (97 ac) of land previously characterized as reclaimed (70 percent or more vegetative cover). These acres were not treated, but were sampled to provide comparisons of ecological advance between reclaimed and unreclaimed portions of the mine.

Sector 2 includes 40.5 ha (100 ac) which were limed, fertilized, and seeded during the fall of 1974 and spring 1975. Some 40,000 autumn olive and 57,000 Virginia pine seedlings were planted during winter 1975-1976.

Sector 3 encompasses 40.5 ha (100 ac) of land which were limed, fertilized, and seeded during the fall of 1975 and spring of 1976. The area was planted with 42,000 autumn olive, 5,000 European alder, and 35,000 loblolly pine seedlings during the 1976-1977 season.

Sector 4, the remaining 43.7 ha (108 ac), was limed, fertilized, and seeded during fall 1976 and spring 1977. The area was planted with 13,000 black locust, 40,000 autumn olive, and 55,000 Virginia pine in the 1977-1978 season.

SECTION 4

TERRESTRIAL SYSTEMS

VEGETATION

A vegetation survey was conducted in fall 1975 to provide baseline data for measuring expected improvement in herbaceous and woody plant cover following application of prescribed land treatments. This was the initial effort to systematically record the kind and extent of seeded, planted, and naturally occurring vegetation.

Methods

The four previously described mined-land sectors--Sector 1 (control) and Sectors 2, 3, and 4 (treatment sites)--serve as areas of measurement for documenting before-treatment conditions. They also accommodate monitoring of treatment response.

A TVA field survey manual (11) provided guidelines on survey methodology and sampling. Two-square-meter (4.64 x 4.64 ft) sample plots were established at a spacing of about one-acre intervals. Their location was determined by placing an acreage grid over a topographic map of the mined area with a scale of 1:20,000. The grid dots of the acreage overlay were then transferred to the project working map which has a scale of 1:6,000. Sample plots were located on the ground by pacing 64-meter (210-foot) intervals. Direction and position were determined by north-south orientation or by using landmarks. Measurements included: (1) tree and shrub species growing on plots, a stem count of each, their basal diameter and height; and (2) grass and legume species, their height and ground cover percentage. Additional data were collected on spoil pH and percentage of natural and reclamation vegetation present.

Results and Discussion

The percentage of vegetative cover, both natural and that which resulted from reclamation efforts, is summarized by sectors in Table 1. Sector 1 includes acreage previously characterized as revegetated. Sectors 2, 3, and 4 represent mined land conditions contributing heavily to offsite damage and are the targets of intensive remedial treatment.

TABLE 1. VEGETATIVE COVER PRESENT ON MINE SITE FALL 1975

Source of Vegetation	Sector 1	2*	3	4
	percent			
Natural	4.7	8.0	6.4	3.3
Reclamation	57.6	28.6	8.3	18.4
TOTAL	62.3	36.6	14.7	21.7

* Partial treatment (limed at 22.4 mt/ha (10 t/ac) fertilized, disked, and seeded to grasses and legumes) applied in fall 1974-spring 1975, or prior to initiation of "Ecological Recovery" study.

Over 42 species of herbaceous plants and 13 woody species were identified. They are listed by their common and scientific names in Appendix D-1. The herbaceous plants fell into four categories: grasses, 7 species, plus several Panicum spp.; legumes, 5 species; composites, 10 species; and miscellaneous, 20 species. Appendices D-2 through D-5 summarize the frequency, mean height, and composition percentage of species encountered by sectors.

Grasses, the primary component in the mine operator's seeding mixture, predominate in every sector (Table 2). The generally low percentage of ground cover on Sectors 2, 3, and 4 was indicative of the relatively barren spoil condition two years after the operator's last seeding effort.

TABLE 2. HERBACEOUS GROUND COVER BY SPECIES CATEGORY AND SECTOR FALL 1975

Species Category	Sector 1	2	3	4
	percent			
Grasses	52.2	28.0	10.6	19.7
Legumes	7.4	3.9	0.5	-
Composites	0.4	0.5	0.6	0.6
Miscellaneous*	2.3	4.2	3.0	1.4
TOTAL	62.3	36.6	14.7	21.7

* Characterized as miscellaneous because of the large number of species involved and their infrequent occurrence.

The number and distribution of forest tree and wildlife shrub seedlings found growing on the mine in fall 1975 were the result of both natural reseeding and several attempts by the operator to establish forest trees and wildlife shrubs (Table 3).

TABLE 3. WOODY PLANTS DISTRIBUTION BY SECTORS FALL 1975

	Sector			
	1	2	3	4
Stems per hectare*	1,307	1,494	2,272	2,061
Stocking percent+	21	16	26	23

* Planting at 1.8 x 1.8 m (6 x 6 ft) approximates 3,000 seedlings per hectare (1,210 per ac).

+ Number of plots on which one or more woody plants occurred divided by the total number sampled times 100.

Planting success is defined as more than 1,500 woody stems per ha (600 per ac) occurring on more than 50 percent of the area (50 percent stocking). Since the number of living stems approached or exceeded the minimum amount needed for success, the limiting factor is their distribution. If established seedlings were distributed equally over the mine site, little additional tree or shrub planting would be needed. Because they were unevenly distributed, the actual count per hectare was much higher than required on a few areas, while many areas had no seedlings at all.

Herbaceous Species--

Grasses comprised over 82 percent of the overall herbaceous ground cover growing on the mine site (Table 4). The predominant species were Kentucky-31 fescue, which was present on 50 percent of the plots and comprised 60 percent of the total vegetative cover, and weeping lovegrass, which occurred on 13 percent of the plots and comprised 12 percent of the cover.

Legumes represented slightly more than 8 percent of the vegetative cover (Table 5). While fescue was the predominant grass, sericea lespedeza was the predominant legume. Sericea, found on 17 percent of the plots, comprised 7 percent of the cover.

Composites made up slightly more than 1 percent of the cover with fall and white asters accounting for three-fourths of the composite vegetation. Windblown seed and weed seed in commercial seed lots contributed to origin of the 10 species (Table 6).

Miscellaneous species comprised over 8 percent of the cover. Cattails and sedges accounted for about half this vegetation (Table 7).

TABLE 4. OCCURRENCE, MEAN HEIGHT, AND PERCENT COMPOSITION OF GRASS SPECIES FOUND ON THE MINE SITE FALL 1975

Species	Occurrence+ (Pct)	Mean Height (cm)	Composition# (Pct)
Broomsedge	9.8	2.2	4.0
Fescue, K-31	50.2	18.5	60.2
Lovegrass, weeping	12.8	17.9	12.3
Millet, foxtail	0.2	15.0	0.1
Millet, wild	0.2	60.0	0.2
Panicum	7.5	25.4	4.1
Ryegrass, perennial	0.2	20.0	*
Switchgrass	1.4	23.7	1.3

+ The number of plots on which a species occurred divided by the total number sampled.

Values represent the relationship of one herbaceous species to another with the total based on 100 percent in terms of existing cover.

* Less than one-tenth of one percent.

TABLE 5. OCCURRENCE, MEAN HEIGHT, AND PERCENT COMPOSITION OF LEGUME SPECIES FOUND ON THE MINE SITE FALL 1975

Species	Occurrence (Pct)	Mean Height (cm)	Composition (Pct)
Clover, red	0.5	8.0	*
Kobe lespedeza	0.2	23.0	0.2
Korean lespedeza	2.1	15.4	1.2
Sericea lespedeza	16.7	52.8	6.9
Sicklepod	0.2	25.0	*

+ The number of plots on which a species occurred divided by the total number sampled.

Values represent the relationship of one herbaceous species to another with the total based on 100 percent in terms of existing cover.

* Less than one-tenth of one percent.

TABLE 6. OCCURRENCE, MEAN HEIGHT, AND PERCENT COMPOSITION OF COMPOSITE SPECIES FOUND ON THE MINE SITE FALL 1975

Species	Occurrence+ (Pct)	Mean Height (cm)	Composition# (Pct)
Aster, fall	3.0	41.9	0.7
Aster, white	1.4	31.8	0.2
Daisy, field	0.7	27.3	0.1
Dandelion	0.5	14.5	0.1
Fleabane	0.5	56.0	0.1
Goldenrod	0.5	76.0	*
Small ragwort	0.2	25.0	*
Tickseed	0.2	20.0	*
White snakeroot	0.2	10.0	*
Wild lettuce	0.5	7.0	*

+ The number of plots on which a species occurred divided by the total number sampled.

Values represent the relationship of one herbaceous species to another with the total based on 100 percent in terms of existing cover.

* Less than one-tenth of one percent.

TABLE 7. OCCURRENCE, MEAN HEIGHT, AND PERCENT COMPOSITION OF MISCELLANEOUS SPECIES FOUND ON THE MINE SITE FALL 1975

Species	Occurrence+ (pct)	Mean Ht. (cm)	Composition# (pct)
Blackberries	1.6	34.1	0.5
Buckwheat: Knotweed	0.2	5.0	0.4
Smartweed, Penn.	1.6	28.7	1.3
Sorrel, red	1.1	3.0	0.2
Cattails	1.8	63.5	1.8
Fern & Fern allies:			
Club moss	0.2	1.0	*
Fern, bracken	0.2	13.0	*
Fern, Hartford	0.4	15.0	*
Fireweed	1.1	25.6	0.5
Fungi: Puffball	0.5	7.0	*
Mushroom	0.7	5.7	0.1
Greenbrier	2.7	19.6	0.2
Lichen, fructicose	0.9	0.8	0.1
Loosestrife, whorled	0.2	25.0	*
Moss	3.7	1.7	0.7
Pokeweed	0.9	69.8	0.5
Purslane, common	0.2	23.0	*
Sedges: Nutsedge	2.1	6.8	0.5
Bulrush	1.8	94.2	1.5

+ The number of plots on which a series occurred divided by the total number sampled.
# Values represent the relationship of one herbaceous species to another with the total based on 100 percent in terms of existing cover.
* Less than one-tenth of one percent.

Trees and Shrubs--

Of 13 tree and shrub species (Table 8), loblolly pine and black locust were most abundant in Sectors 1 and 4. The pines--loblolly, shortleaf, and Virginia--predominated in Sector 2. Loblolly and shortleaf pine and black locust were most abundant in Sector 3. No inferences can be drawn from the occurrence of these species by sectors. Their incidence is probably a reflection of planting preferences by the operator in a particular season.

Sectors with the most ground cover had a fewer number of trees and shrubs per hectare than sectors with least ground cover. For example, Sector 1 (control) had 62 percent herbaceous ground cover and only 1,307 seedlings per ha (529 per ac), while Sector 3 had only 15 percent ground cover, but 2,272 seedlings per ha (920 per ac).

Mean heights and basal diameters of woody plants growing on the mine site in fall 1975 are compared by species in Table 9. The ability of autumn olive and shrub lespedeza to grow well on acid strip mine sites is reflected in their initial growth performance. In some instances these two shrub species outgrew earlier planted loblolly pine and black locust. While the forest tree species should eventually dominate because of their silvicultural characteristics, the exhibited fast growth rates of the two shrubs indicate their value as erosion control species.

Spoil pH--

Core samples 10-15 cm (4-6 in.) deep were taken on each plot and pH was determined in the laboratory on < 60 mesh samples (1:1 soil to water ratio on a weight basis). A comparison of spoil pH values by sectors fall of 1975 was as follows:

	Sector			
	1	2	3	4
Range	3.0-7.2	2.8-6.1	2.9-4.8	2.6-5.1
Mean	4.9	3.8	3.5	3.6

Sector 3 with the lowest mean pH (3.5) had the lowest percent ground cover (14.7) while Sector 1, with the highest mean pH (4.9), had the highest percent ground cover (62.3).

Summary

A survey was conducted in fall 1975 to record the kinds and amount of vegetation, both natural and that which resulted from the mining operator's reclamation efforts. Baseline data show:

1. Only 39 ha (97 ac) of the approximately 162 ha (400 ac) comprising the mine site had been satisfactorily revegetated.

TABLE 8. STEM DENSITY AND STOCKING OF WOODY SPECIES BY SECTORS FALL 1975

Species	Sector 1		2		3		4		Mean, all Sectors	
	Stems per ha +	Stocking Percent #	Stems per ha	Stocking Percent	Stems per ha	Stocking Percent	Stems per ha	Stocking Percent	Stems per ha	Stocking Percent
Autumn olive	212	4.2	-	-	-	-	49	1.0	79	1.6
Filbert	-	-	-	-	49	1.0	-	-	11	0.2
Locust, black	423	5.7	170	3.1	593	10.0	587	8.9	439	6.8
Maple, red	-	-	101	2.1	-	-	-	-	23	0.5
Oak, sawtooth	-	-	52	1.0	49	1.0	-	-	45	0.5
Pine, loblolly	494	10.0	204	3.1	445	3.0	887	12.8	462	7.5
Pine, shortleaf	-	-	203	4.1	741	10.0	147	1.9	248	3.7
Pine, Virginia	106	2.1	559	3.1	198	4.0	342	1.9	293	2.7
Shrub lespedeza	36	0.7	-	-	-	-	-	-	11	0.2
Sourwood	36	0.7	52	1.0	-	4.0	49	1.0	102	1.8
Sumac, staghorn	-	-	-	-	99	1.0	-	-	45	0.2
Sweetgum	-	-	-	-	49	1.0	-	-	11	0.2
Yellow-poplar	-	-	153	1.0	49	1.0	-	-	45	0.5

+ A 6 x 6 spacing equals approximately 3,000 stems per hectare.
# The number of plots on which a species occurred divided by the total number sampled.

TABLE 9. COMPARISON OF MEAN HEIGHT AND BASAL DIAMETER OF WOODYSPECIES BY SECTORS FALL 1975

Species	Sectors 1 Height (meters)	1 Diameter (cm)	2 Height (meters)	2 Diameter (cm)	3 Height (meters)	3 Diameter (cm)	4 Height (meters)	4 Diameter (cm)	Mean for all Sectors Height (meters)	Mean for all Sectors Basal Diameter (cm)
Autumn olive	1.5	4.0	-	-	-	-	1.8	5.0	1.6	4.1
Filbert	-	-	-	-	0.2	3.0	-	-	0.2	3.0
Lespedeza, shrub	1.5	2.0	-	-	-	-	-	-	1.5	2.0
Locust, black	1.3	2.6	0.6	1.7	0.8	1.6	1.6	3.7	1.2	2.5
Maple, red	-	-	0.2	1.0	-	-	-	-	0.2	1.0
Oak, sawtooth	-	-	0.1	1.0	0.6	4.0	-	-	0.4	2.5
Pine, loblolly	1.4	4.9	1.7	5.3	0.3	5.3	0.5	1.9	1.0	3.8
Pine, shortleaf	-	-	0.4	1.8	0.4	1.1	0.1	0.1	0.4	1.1
Pine, Virginia	0.4	1.0	0.6	1.7	0.7	2.6	0.3	0.6	0.5	1.6
Sourwood	0.1	1.0	0.3	1.0	0.3	0.8	0.2	0.1	0.3	0.8
Sumac, staghorn	-	-	-	-	0.1	1.0	-	-	0.1	1.0
Sweetgum	-	-	-	-	0.2	1.0	-	-	0.2	1.0
Yellow-poplar	-	-	0.2	1.0	0.1	0.2	-	-	0.1	0.6

2. The 39 ha (97 ac) judged to be reclaimed had 62 percent herbaceous cover; the remaining 125 ha (308 ac) had an average herbaceous cover of 24 percent.

3. In terms of total vegetation growing on the mine site, only 17 percent was from natural sources; the other 83 percent resulted from reclamation.

4. Some 55 species of plants were found. These included four categories of herbaceous plants--grasses, legumes, composites, and miscellaneous--and forest tree and wildlife shrubs.

5. Predominating species were those seeded or planted in the revegetation efforts. Kentucky-31 fescue comprised 60 percent of the herbaceous vegetative cover; weeping lovegrass, 12 percent; and sericea lespedeza, 7 percent. Loblolly pine and black locust were the predominant forest tree species.

6. The ability of autumn olive and shrub lespedeza to grow well on acid strip mine sites is reflected in their initial growth performance.

7. Mine sectors with lesser amounts of herbaceous ground cover tended to have more woody plants per hectare.

8. Tree and shrub seedlings established per hectare approached minimum numbers needed for reclamation success. If they were evenly distributed over the mine site, little additional planting would be needed.

9. Vegetative cover percentage decreased with decrease in spoil pH.

SPOIL CHEMISTRY

A separate study (12) initiated in 1974 before start of remedial treatment involved an analysis of soils from selected areas on the mine site. These investigations were conducted to determine why vegetation became established on some areas and not on others.

Study areas included the Thompson Creek drainage which contains some "orphan" banks from past mining. Spoils on this area were sampled along seven transects running from the highwall to the edge of the mine outslope. Fifty plots were also established at random on seven sites at scattered locations from the entrance to the far end of the mine. On these, plot centers were located on boundaries of vegetated and nonvegetated areas. Spoils were sampled at three points on each side of the boundary with samples taken at the surface and at depths of 10 cm (3.9 in.) and 30 cm (11.8 in.).

Samples were analyzed for pH, calcium, magnesium, potassium, phosphorus, iron, aluminum, manganese, zinc, compaction, moisture content, surface temperature, and color. Analyses indicated all spoils contained low concentration of nutrients. Potassium, phosphorus, manganese, and zinc were in the deficiency range of most plants. The solubility of aluminum and iron increased with low pH, thus increasing the probability of their interactions with and decreased availability of other plant nutrients. Nonvegetated areas had lower values than vegetated areas for pH and potassium, and higher values for exchangeable magnesium, calcium (four of seven areas), iron, aluminum (on unlimed, unfertilized areas) and penetration resistance (compaction).

TERRESTRIAL FAUNA

The study provides an opportunity to determine the response of terrestrial fauna (small mammals and songbirds) to remedial spoil treatments. Accordingly small mammal and avifauna censuses were begun in May and June 1976. Counts of bird populations are scheduled to continue through four successive winters and breeding periods--to 1980. Small mammal censuses, conducted during the months of May and November are scheduled through 1981. Very few studies have been reported in the United States that quantify bird population successional patterns on coal strip mined areas in comparison with natural habitats. Likewise, very few studies of small mammal succession have been made on lands stripped for coal. Data collected will be correlated with changes in mined land conditions expected from application of prescribed revegetation treatments.

Since collection of terrestrial fauna data did not begin until after treatments were initiated on two-thirds of the area, results will be presented in a Phase II report.

SECTION 5

AQUATIC SYSTEMS

Surveillance of conditions in Ollis Creek and its tributaries began in August 1970 and continued periodically through October 1972--the period of mining and conventional reclamation (8, 9). Sampling was resumed in August 1975 to provide further environmental baseline and have data for evaluating effects of the intensive reclamation on the aquatic ecosystem. This section documents historical conditions and those occurring from August 1975, when monitoring was resumed, to July 1976.

DESCRIPTION OF SAMPLE STREAMS

Ollis Creek has been generally described in a previous section. Length of the stream is approximately 15 km (9.4 mi). Substrate is mainly boulder and bedrock. Ollis Creek drops about 20 m in elevation per km (105 ft per mi).

No Business Creek, a nearby watershed, was also sampled as a reference area to compare potential water quality, fish, and aquatic invertebrates with Ollis Creek. No Business Creek differs somewhat from Ollis Creek. It is a much smaller watershed area--704 ha (1,740 ac) compared to 2,798 ha (6,912 ac) for Ollis Creek--of shorter length--3.5 km (2.2 mi), compared to 17.4 km (9.4 mi)--has less fluctuation in streamflow, and different substrate (more gravel, rubble). Alkalinity and hardness for unaffected portions of the two streams are similar. No Business Creek flows into Hickory Creek (Cumberland River drainage) while Ollis Creek flows into Big Creek (Tennessee River drainage), and consequently a slightly different fish species assemblage is present. No Business Creek has a gradient of about 28 m per km (150 ft/mi); however, the gradient in the area sampled is much lower with 15 m/km (80 ft/mi).

A limited amount of remedial treatment of stripped land was carried out during late 1974 and early 1975 on mined areas in the Thompson Creek and Ollis Creek watersheds (Land Sectors and Treatment, Sector 2). This partial treatment may have influenced early monitoring data to some extent, although its impact on the main drainage is expected to be slow. However, since no aquatic monitoring was done on any of the drainages between 1972 and the remedial treatment, it is difficult to assess the immediate effects of the treatment.

METHODS AND MATERIALS

Aquatic systems baseline data are those collected "during mining and conventional reclamation," and for most stations include data collected from August 1975 through July 1976. Since some limited remedial reclamation was applied to mined areas on Thompson Creek and a minor part of Ollis Creek

during late 1974 and early 1975, these data are also identified and included in tables and discussion. Data for the specific drainage are identified as collected "before remedial treatment" or "during remedial treatment." Methods employed in the recent monitoring are described below.

Water Quality

Water quality samples were taken monthly at each of the stations shown in Figure 1. Alkalinity and acidity were determined within a few hours by titration (13). Dissolved oxygen and pH were determined in the field with portable meters. A portion of the sample was preserved for laboratory analyses. Water analysis was performed by the TVA Division of Natural Resources Services Laboratory Branch, Chattanooga.

Aquatic Invertebrates

Aquatic invertebrates were sampled monthly with square foot Surber samplers at each station on Ollis Creek, its tributaries, and No Business Creek. Four samples were collected at each sample site. Surber samples were preserved in 10 percent formalin and returned to the laboratory. Qualitative samples were also collected in the vicinity of each station to complete a species list. Samples were picked by hand and all organisms were placed in 65 percent ethanol. All invertebrates were identified to the lowest possible taxon and weighed (blot dry weight) to the nearest 0.1 milligram on a Mettler Balance. Samples during the 1970-1972 period were collected with a sweep net and cannot be considered as quantitative.

Fish

All stations on Ollis Creek and its tributaries and No Business Creek were sampled monthly with a battery-powered, pulsed d.c. backpack electrofishing unit. A 30 m (100 ft) section of stream with both a pool and riffle was fished at each station. Electrofishing began at the lower pool end of each stream section and proceeded upstream toward the riffle. All fish that were stunned by the current were picked up with a dip net. Fish taken within the sample area were identified to species, measured, weighed, and returned to the water alive. Fish of uncertain taxonomic status were preserved in 10 percent formalin and returned to the laboratory for identification.

RESULTS AND DISCUSSION

Water Quality

Water quality in Thompson Creek, Station 8, the stream which drains one of the worst problem areas, was apparently degraded during mining. On July 25, 1972, approximately three months after the end of mining, pH readings reached a low of 3.6. On the same date sulfates totaled 230 milligrams/liter (mg/l). Manganese values as high as 31 mg/l and iron values as high as 1.5 mg/l were recorded (Appendix E-1). Data from Yellow Branch, another stream in close proximity to mining activity, showed the same general trends, although the results were not as dramatic (Appendix E-2). On

September 8, 1971, the pH dropped to 5.0 from a previous pH average of 6.9 while iron reached a peak value of 4.8 mg/l, manganese 5.4 mg/l, and sulfates 200 mg/l.

The same pattern was evident near the mouth of Ollis Creek. The lower Ollis Creek station, Station 1, (Mile 0.78) was apparently degraded during mining (Appendix E-3). Total alkalinity and pH generally decreased, while total acidity, sulfate, iron, manganese, total hardness, and conductivity increased. A low pH of 4.5 was recorded on October 25, 1972. This poor water quality indicated that the entire stream was impacted by acid drainage.

Water quality at the lower Ollis Creek station showed little improvement after partial remedial treatment. The pH dipped to a low of 4.5 in October 1975 as it did in October 1972. Sulfate, iron, and manganese concentrations remained high, but they did not reach the levels measured during mining. Water quality apparently continued to degrade after mining and conventional reclamation on Yellow Branch, Station 5 (Appendix E-2). The pH reached a low of 4.7 on October 30, 1975. Total iron concentrations reached 25 mg/l and manganese, 16 mg/l on September 17, 1975. No baseline data prior to remedial treatment were collected on Thompson Creek (Station 8) or on Unnamed Tributary (Station 7) of Ollis Creek.

Laurel Branch, Station 4, had only a small part of its lower watershed affected by surface mining and conventional reclamation during 1970-1972. This area has received no remedial treatment to date. The stream is subject to other watershed abuses (particularly road construction) that are complicating factors in assessing the potential recovery of Laurel Branch which had fluctuating water quality during 1975-1976. Laurel Branch (Appendix E-4) has shown high turbidity during the sampling period. The pH showed a slight improvement, with the lowest value of 4.2 in October 1975. There was a general upward trend in the following months with values up to 6.8 recorded. Iron values remained relatively high during 1975-1976, with the highest value of 4.9 mg/l recorded in February 1976. Manganese showed some downward trends, but concentrations remained at unacceptably high levels (1.3 mg/l in May). The lowest pH (3.4) on Unnamed Tributary (Station 7) was recorded before remedial treatment (Appendix E-5). Lowest value during remedial treatment was 4.7 with one reading up to 6.6 (December 1975). Iron concentrations remained high during remedial treatment (29 mg/l in February 1976). There was an apparent downward trend in manganese with a high of 23 mg/l during remedial treatment, but the concentrations were still unacceptable (10 mg/l in February 1976). Sulfate levels ranged from 210 to 790 mg/l with an average of 440 mg/l during the monitoring period.

Water quality remained substandard at the lower Ollis Creek station, Station 1, during remedial treatment (Appendix E-3). Although pH did not fall below 5.1, total iron and manganese continued at high levels reaching peaks of 0.78 and 1.4 mg/l, respectively (February 1976). The same pattern emerged during remedial treatment on Thompson Creek, where pH usually remained below 5.0 with a low reading of 3.8 (Appendix E-1). Iron (maximum 3.1 mg/l) and manganese (maximum 2.4 mg/l) remained at unacceptably high concentrations, although they showed some improvement during remedial treatment. On Yellow

Branch the pH remained above 5.0, with one reading as high as 6.9. Sulfate, iron, and manganese concentrations decreased. These data suggest an improving trend in the water quality of Yellow Branch and possibly Thompson Creek during remedial treatment. Future sampling will determine whether this change is permanent or temporary due to the lime applications.

The precipitation data did not document the occurrence of any unusually heavy storms during the August 1975 to July 1976 sampling period. Average annual water quality parameter measurements can be inordinately affected by storm-associated samples (i.e., turbidity and some constituents which normally occur in trace or undetectable amounts will markedly increase). Without flow data, water quality data as well as biotic data will be more difficult to interpret because they are so strongly influenced by flow regime.

Aquatic Invertebrates

Species of aquatic invertebrates collected in Ollis Creek and its tributaries during mining, after partial remedial treatment, and during remedial treatment are listed in Appendix F-1. The data collected during mining were qualitative, therefore, the only valid comparisons that can be made are on species occurrence. Number of taxa declined drastically from 71 collected during mining to 40 after partial remedial treatment. Some increase in diversity was noted during remedial treatment (49 taxa collected); however, this difference may be at least partially due to the greater number of months sampled during mining and conventional reclamation. Most of the declines between mining and reclamation were in taxa of ephemeropterans, plecopterans, odonates, and dipterans. Mean numbers of aquatic invertebrates collected during 1975-1976 at three Ollis Creek stations, Yellow Branch, Unnamed Tributary, and Thompson Creek, are given in Appendix F-2. Mean number of invertebrates collected after remedial treatments were much higher during the following nine months at all stations except Laurel Branch (same) and Thompson Creek (higher during remedial treatment). An inadequate number of samples was taken during the partial treatment period to make conclusions about trends, and some of the apparent fluctuations in number may be due to "natural" seasonal fluctuations in abundance or to scouring effects associated with heavy precipitation and resultant high flows. Further sampling will delineate the relationships involved. Data on the monthly abundance of aquatic invertebrates and complete species lists at individual sample stations are in Appendices F-2 through F-10.

Examination of data from Thompson Creek, Station 8, which was heavily impacted by mining, indicated dramatic increases in the number of species collected (Appendix F-11). Number of taxa increased from 13 during mining to 26 during remedial treatment. Most dramatic increases were in the odonates, dipterans, and coleopterans.

Thompson Creek began to show some increases in the number of species collected in later months. These increases indicate some natural recovery as well as some possible changes due to initial remedial treatments on Thompson Creek. Number of taxa collected declined at Ollis Creek mile 3.37, Station 3,

from 17 during mining to 14 during remedial treatment (Appendix F-12). Most dramatic declines were in the number of odonate species. The number of dipteran taxa increased in the later samples.

Fish

Taxa of fish collected in Ollis Creek and its tributaries during 1970-71 and 1975-76 are in Appendix G-1. Common and scientific names are presented in Appendix G-2. Number of taxa collected declined from seven during mining to four during remedial treatment. Fish collected during 1970-71 were identified only to genera in some cases, and there is doubt about the identification of at least one species (least darter). Stonerollers, Campostoma anomalum; Pimephales sp.; and least darter, Etheostoma microperca, were absent from the 1975-76 collections. The least darter is not known to occur in the Tennessee River drainage and probably represents a misidentification. However, the occurrence of one or more species of darters could be expected in a stream the size of Ollis Creek. Species occurrence data, therefore, indicated a decline since mining. Fish species are generally slower to recover than water quality or benthic invertebrates, and a reintroduction of more tolerant native species may be desirable after continued improvement of the ecosystem.

COMPARISON WITH A REFERENCE STREAM

Water Quality

Comparisons of selected water quality parameters from Ollis Creek and Thompson Creek with those from corresponding stations on No Business Creek are shown in Appendix H-1. Both streams have naturally soft water due to the similar geology in the two watersheds. However, the pH was consistently lower at Thompson Creek (minimum of 4.3) than at the No Business Creek upper station (minimum of 5.8). Sulfate, iron, and manganese concentrations were relatively high in Thompson Creek. Although these parameters were measured on only one date at the upper No Business Creek station, the values were several orders of magnitude lower than on Thompson Creek.

The same type of indication of acid mine drainage was evident on the lower Ollis Creek station. A minimum pH value of 5.1 was recorded for Ollis Creek while No Business Creek Station 1 recorded 5.8. Sulfate, iron, and manganese were always higher in Ollis Creek. No Business Creek did have one relatively high iron concentration (0.56 mg/l). This value indicated that there may be high "natural" iron concentrations in softwater streams draining watersheds similar to Ollis Creek.

Aquatic Invertebrates

Comparisons of benthic fauna collected in Ollis Creek and Thompson Creek and at corresponding stations on No Business Creek were made to detect differences in the biota of an affected and unaffected or "control" watershed (Appendix H-2). There were some differences in substrate, watershed size, and flow characteristics between the two streams. Ollis Creek has a much larger watershed with the stream more susceptible to drastic flow fluctuations. No

Business Creek has a more rubble and gravel substrate while Ollis Creek more boulder and bedrock; however, these comparisons are useful to examine differences in biotic potential of the two streams. A total of 44 taxa was collected from Station 1 (Mile 0.78) on Ollis Creek. Almost twice as many (83) taxa were collected from the comparable station on No Business Creek. This difference in number of species was most evident in the Ephemeroptera and Plecoptera (4 taxa from Ollis Creek, 14 from No Business Creek). Total biomass of all organisms collected from No Business Creek was almost double that of Ollis Creek. Total numbers were almost seven times greater at the No Business station. Species diversity (Table 10) was higher at No Business Creek Station 1 (6.29) than at Ollis Creek Station 1 (4.24).

The middle station on No Business Creek (Station 2) also showed much greater diversity than Station 6 on Ollis Creek. Eighteen taxa were taken from Ollis Creek, 53 from No Business Creek. Four taxa of Ephemeroptera and Plecoptera were collected from Ollis Creek, and 17 from No Business Creek. Total biomass collected was almost 10 times greater in No Business Creek than in Ollis Creek. Species diversity was much greater on No Business Creek with No Business Creek Station 2 recording 7.54 while at the corresponding Ollis Creek station species diversity was 3.36 (Table 10).

The differences in number of taxa persisted in the upper stations (Table 10) on the two streams (57 for No Business Station 3 as compared with 29 for Thompson Creek). However, the total biomass was greater for the organisms in Thompson Creek. These differences in biomass were due mainly to the large biomass of organisms such as crayfish, odonates, and trichopterans (Diplectrona). The number of species of ephemeropterans and plecopterans was much higher in No Business Creek (4 species as compared with 20). The total number of organisms collected was more than three times as great at the No Business Creek station. Diversity was higher in No Business Creek (7.86) than in the Thompson Creek station (4.55).

Fish

A total of seven species was collected in No Business Creek (Appendix I-1) while four species were collected in Ollis Creek during 1975-1976 (Appendix I-2). Creek chub was the only species common to both streams (Appendix I-3). Emerald shiner, white sucker, and bluegill were unique to Ollis Creek, while stoneroller, bluntnose minnow, blacknose dace, northern hog sucker, stripetail darter, and arrow darter were collected only in No Business Creek. The absence of darters from Ollis Creek is an indicator of environmental problems. The emerald shiners, white suckers, and bluegills in Ollis Creek were restricted to the reservoirs. Differential land use of the watersheds, size of the two streams, and blockage of immigration by the reservoirs on Ollis Creek probably contributed to the differences in species occurrence in the two streams.

SUMMARY

Long-term effects of remedial treatment on the water quality and the aquatic communities of Ollis Creek are yet to be determined; however, some

TABLE 10. COMPARISON OF AQUATIC ABUNDANCE DATA (SQUARE FOOT SURBER SAMPLES) COLLECTED FROM CORRESPONDING STATIONS ON OLLIS CREEK AND THOMPSON CREEK, AND NO BUSINESS CREEK FROM NOVEMBER 1975 THROUGH JULY 1976

	Ollis Creek Station 1	No Business Station 1	Ollis Creek Station 6	No Business Station 2	Thompson Creek	No Business Station 3
Total Number	142	932	117	1,126	304	1,095
Range	1-29	1-509	1-53	1-206	1-116	1-122
Mean	35.5	233.0	29.2	281.5	76.0	273.8
Total Biomass (m)	11.2	25.9	8.5	42.7	27.6	20.0
Total Taxa	22	44	17	54	27	56
Species Diversity*	4.2	6.3	3.4	7.5	4.6	7.9

* According to Marglef (14).

initial changes are noted in this baseline report. Upper Ollis Creek, Thompson Creek, Yellow Branch, and Unnamed Tributary have shown increases in pH, and decreases in alkalinity, sulfate, iron, and manganese. These changes were small; however, in all cases, at least one water quality parameter remained at unacceptable levels. The level of water quality parameters at Station 1 indicated the entire length of Ollis Creek was affected by acid mine drainage. Laurel Branch was relatively unaffected by surface mining, but other activities (road construction) contributed to water quality problems. Water quality parameters on Laurel Branch remained generally constant, with some change during the 1975-1976 sampling.

Water quality of Ollis Creek and its tributaries was different from that of an undisturbed watershed, No Business Creek. On Ollis Creek, there was evidence of concentrations of water quality parameters associated with acid mine drainage (low pH, high sulfates, iron, and manganese). These parameters indicated a degradation that began shortly after surface mining and has continued. Some preliminary changes appear to be taking place in treated portions of Ollis Creek (e.g., an increase in pH), but only additional monitoring will be able to determine whether these trends will continue.

The total number of taxa of aquatic invertebrates in Ollis Creek and its tributaries declined drastically from 71 during mining to 40 after conventional treatment and increased to 49 during remedial treatments. These increases were most evident in Thompson Creek, which was heavily impacted by mining. Seasonal fluctuations would appear to account for the lowered mean numbers of invertebrates collected in Ollis Creek and its tributaries from August through October 1975. During this period streamflows were low and water temperatures elevated. Mean numbers increased in the nire months following October. Future planned monitoring should provide data to more accurately assess benthic community changes and help evaluate which changes are seasonal and which are responses to remedial treatments.

At least three species of fish have disappeared from Ollis Creek since 1970. When compared with No Business Creek, Ollis Creek had only half as many species present during early remedial treatment monitoring. These differences are probably due to the direct or indirect impacts of acid mine drainage. The species collected on Ollis Creek could be considered relatively tolerant of environmental stresses. It appears from collection localities that the species present are living in the reservoirs and not in the flowing portions of Ollis Creek.

SECTION 6

RESERVOIR SEDIMENTATION

Beginning in October 1970 surveys of sediment deposition in Reservoir No. 2 (Figure 1) were taken annually by TVA's Division of Natural Resources Services to monitor effects of the mining.

From closure of the dam in 1964 until 1970, sediment deposition totaled 14,796 meters^3 (m^3) (12 acre-feet) resulting in a storage loss of 1.8 percent and leaving a storage capacity of 800,217 m^3 (649 acre-feet). Between October 1970 and October 1974, sediment deposition totaled 36,990 m^3 (30 acre-feet) ranging from 617 m^3 90.5 acre-feet) in 1971 to 160,029 m^3 (13 acre-feet) in 1973. Reservoir storage loss for the four-year period amounted to 3.6 percent and left a storage capacity of 763,227 m^3 (619 acre-feet).

The low rate of sediment deposition the first year after mining was attributed to the slow movement of sediment down the outslopes and into small drains below mined areas. In 1972 and 1973, with rainfall averaging some 45.7 cm (18 in.) above normal, this sediment, plus additional contributions, was deposited in the reservoir. Intense storms in the spring of these two years resulted in heavy washing of watershed logging roads and in washing out of small sediment traps in drains below mined areas. The rate of deposition in 1974 was less than half the rate of 1973 even though rainfall during the year was 189.5 cm (74.6 in.)--58.4 cm (23 in.) above normal.

These annual surveys are continuing and provide a basis for measuring improvements following remedial treatment of the affected mine acreage.

SECTION 7

PHASE II REPORT

This Phase I report establishes baseline and initial treatment conditions. Phase II will evaluate early effects of remedial reclamation treatments through continued monitoring of the terrestrial and aquatic ecosystems.

Except for some followup land treatment required by vegetation establishment failures, all remedial work scheduled on the affected 162 ha (308 ac) through the 77-78 planting season has been completed. Results of the intensive treatment applied over the three-year period will be evaluated in terms of vegetation establishment, water quality, aquatic invertebrate and fish changes, and reservoir sedimentation rate. Response of terrestrial fauna (small mammals and songbirds) will also be reported.

REFERENCES

1. USDA Soil Conservation Service. 1959 (Rev. 1972). General Soil Survey Map of Campbell County, Tennessee. I.D. 4-R-22617. Nashville, Tennessee.

2. Wilson, C. W., Jr., and J. W. Jewell, E. T. Luther. 1956. Pennsylvania Geologic Survey of the Cumberland Plateau. State of Tennessee Department of Conservation, Division of Geology. Nashville, Tennessee.

3. Luther, E. T. 1959. The Coal Reserves of Tennessee. State of Tennessee Department of Conservation and Commerce, Division of Geology Bulletin 63, Nashville, Tennessee.

4. Keystone Coal Industry Manual. 1976. A McGraw-Hill Publication, New York, New York 10020.

5. Fowler, D. K. 1973. Wildlife Habitat Improvement Demonstration, Ollis Creek Coal Strip Mine, Campbell County, Tennessee. Progress Report No. 1, Ident. No. 885-43-01.02. FF&WD, TVA, Norris, Tennessee. January.

6. Vogel, W. G. 1971. Needs in Revegetation Research on Surface-mined Land. Proc. Revegetation and Economic Use of Surface-mined Land and Mine Refuse Symposium. Pipestem State Park, West Virginia. December.

7. Maddox, J. B. and D. K. Fowler. 1974. Ollis Creek Coal Strip Mine Reclamation: Problem Analysis and Proposed Solution. Campbell County, Tennessee. Report No. 999-43-10. FF&WD, TVA, Norris, Tennessee.

8. TVA Water Quality Branch. 1972. Water Quality Data on Ollis Creek, Summary Tables, TVA Division of Environmental Planning, Chattanooga, Tennessee.

9. TVA Environmental Biology Branch. 1972. Biological Surveillance of Ollis Creek. Internal Report TVA Division of Environmental Planning, Muscle Shoals, Alabama.

10. Maddox, J. B. 1973. Influence of Lime and Topsoil on Vegetation Establishment of Acid Spoils. FF&WD, Internal Report, TVA, Norris, Tennessee.

11. McCarthy, Dennis. 1975. Field Survey Manual for the Vegetation of the Tennessee Valley. FF&WD, TVA, Norris, Tennessee.

12. Ott, Donald Wesley. 1978. Comparative Analyses of Adjacent Vegetated and Bare Strip Mine Spoils. Ph.D. Dissertation, The University of Tennessee, Knoxville, Tennessee. 70 pp.

13. American Public Health Association. 1960. Standard Methods for the Examination of Water and Wastewater, Including Bottom Sediment and Sludges. New York.

14. Margalef, R. Diversidad de Especies en las Communidas Naturales. Proc. Inst. Biol., Apl. 9, 5. 1951.

APPENDIX A

KOPPERS PROPERTY

Proposed Contract Reclamation Provisions

Contractor agrees to perform in accordance with the following standards and to the satisfaction of TVA reclamation and conservation work upon all lands which are affected by the strip mining (including surface auger) of any coal supplied under this contract.

a. Contractor shall, as closely as practicable following the mining operation, cover coal faces and bury all toxic materials including coal wastes and strongly acid shales.

b. Contractor shall seal off any breakthrough to former underground mines.

c. Contractor shall conduct the mining in such a manner as to keep the drainage free of spoil. This will include no mining activities (except building roadways) within 100 feet of any stream channel.

d. Contractor shall control water from the mines and haul roads by:

   (1) Channeling runoff into drainages either naturally noneroding or made that way through construction of checks, or

   (2) by impoundments, or

   (3) a combination of (1) and (2).

e. Contractor shall cover all holes at the face that have been made by augers.

f. Contractor shall grade the spoil banks as necessary to provide for the reestablishment of vegetation.

g. Contractor shall conduct mining and reclamation so that any spoil placed on the slope below the bench will be handled with the objective of preventing landslides. This provision will require that all organic material in the proposed cut and fill sections be removed and windrowed just below the calculated toe of the fill material. It will also control the bench width of the first cut in relation to the steepness of slope as follows:

28°+	No surface mining
26.1° - 28°	80'
24.1° - 26°	105'
22.1° - 24°	125'
20.1° - 22°	145'
18.1° - 20°	165'
0 - 18°	No restrictions

In special instances where slope reduction is permitted, the bench widths may be exceeded as determined by TVA.

No materials from second or subsequent mine cuts will be placed anywhere on outer one-third of the fill bench created by first mine cut.

h. Contractor shall seed, mulch, and fertilize by hydroseeder all spoil material on all outslopes and other critical areas as determined by TVA within one week of final placement. All other areas will be seeded and fertilized on the same schedule. Immediate reseeding, remulching, and refertilization will be required in case of all failures. During the first winter planting season, deep-rooted trees and wildlife food and cover plants will be planted on all outslopes and other areas designated by TVA.

i. To the maximum extent practicable, the foregoing work shall be performed at the same time the mining operation is taking place, and all the above work shall be completed no later than 24 months after the delivery of all the coal supplied under this contract, unless TVA agrees to a longer period of time.

j. To help develop improved mining and reclamation techniques, Contractor shall cooperate with TVA in conducting selected tests and demonstrations in conjunction with the contract mining operation. All costs of this work will be borne by TVA, based on accurate records maintained by the Contractor.

TVA shall have the right to inspect the Contractor's mining operation and the lands involved from time to time to determine the Contractor's compliance with the foregoing standards. TVA shall at all times be the sole judge as to whether Contractor is complying with the standards set out above. TVA, in its discretion, may accept as fulfillment of the requirements of this contract compliance by the Contractor with applicable reclamation laws having standards comparable to the foregoing.

APPENDIX B

SILT STRUCTURES BUILT
IN OLLIS CREEK WATERSHED

Number of Silt Control Structures	Location	Date
1	Below the road on Ollis Creek	5-22-70
1	Below the road on Ollis Creek	5-28-70
1	Below the road on Ollis Creek	6-19-70
2	Below the main road near the Flatwoods section	7-24-70
1	Rock structure off the haul road - Ollis Creek	9-25-70
1	Rock structure in head of Ollis Creek	9-25-70
1	Rock structure on Ollis Creek	10-9-70
2	Structure completed on Yellow Branch	10-9-70
1	Rock structure on Ollis Creek	10-23-70
1	Rock structure on Thompson Creek	10-23-70
4	Rock structures on Thompson Creek	5-4-71
4	Rock structures on Number Thirteen Hollow	10-5-71
1	Rock structures in the head of Ollis Creek	12-20-71
2	Silt structures in a small tributary off Ollis Creek	1-18-72
5	Silt structures built in Number Twelve Hollow	10-27-71

APPENDIX B (Continued)

Number of Silt Control Structures	Location	Date
1	Rock structure below haul road in Ollis Creek	1-18-72
2	Both rock structures on Ollis Creek were rebuilt on Ollis Creek	2-17-72
1	One additional rock structure was built on Ollis Creek	2-17-72
3	Silt basins were built below the three basins which were constructed in April and May 1970 near the old road leading to the lake	
6	Earthern silt structures were built and/or rebuilt between April and November 1974: One each in Number Twelve Hollow, Number Thirteen Hollow, and Yellow Branch; three in small Ollis Creek tributaries west of Yellow Branch	11-8-74

APPENDIX C

SUMMARY OF SURFACE MINE TEST AND DEMONSTRATION ACTIVITIES IN OLLIS CREEK WATERSHED

Establishment Date	Description
December 1970	Revegetation demonstration with municipal compost.
March 1971	Grass and legume seeding test demonstration.
April 1971	Demonstration of wildlife habitat improvement--initial planting of wildlife food and cover plants.
October 1971	Mulching materials soil conditioning test--pine bark, hardwood shredded bark, municipal compost, lime.
November 1971	Neutralization of Ollis Creek acid spoils--greenhouse pot experiment, Soils and Fertilizer Branch, Muscle Shoals, Alabama.
April 1972	Wildlife habitat improvement demonstration--5,700 plants added.
April 1972	Wildlife plant pH tolerance and screening studies--seven species.
April 1972	Lime and topsoil as site modifiers.
June 1972	Documentation of improvement in soil acidity brought by weathering and use of spoil amendments.
October 1972	Effect of various fertilizer concentrations on germination of grass and legume seed applied to Ollis Creek spoils--greenhouse pot experiment, Norris, Tennessee.

APPENDIX C (Continued)

Establishment Date	Description
April 1973	Wildlife habitat improvement demonstration--6,850 plants added.
April 1973	Wildlife plant pH tolerance and screening test--11 species.
April 1973	Tests of selected woody and herbaceous plants to grow on acid spoils.

APPENDIX D

(Supplemental information on vegetation)

TABLE D-1. PLANT SPECIES FOUND ON THE MINE SITE FALL 1975

Common name	Scientific name
Grasses	
Broomsedge	Andropogon virginicus L.
Fescue, K-31	Festuca arundinacea Schreb., (var.)
Lovegrass, weeping	Eragrostis curvula (Schrad.) Nees
Millet, foxtail	Setaria italica (L.) Beauvois
Millet, wild	Echinochloa crusgalli (L) Beauv.
Panicum	Panicum spp.
Ryegrass, perennial	Lolium perenne L.
Switchgrass	Panicum virgatum L.
Legumes	
Clover, red	Trifolium pratense L.
Kobe lespedeza	Lespedeza striata (Thunb.) H. & A.
Korean lespedeza	Lespedeza stipulacea Maxim.
Lespedeza sericea	Lespedeza cuneata (Dumont) G. Don
Sicklepod	Cassia tora L.
Composites	
Aster, fall	Aster spp.
Aster, white	Aster spp.
Daisy, field	Chrysanthemum spp.
Dandelion	Taraxacum officinale Wiggers
Fleabane	Erigeron spp.
Goldenrod	Solidago spp.
Wild lettuce	Lactuca scariola L.
Small ragwort	Senecio smallii Britton
Tickseed	Coreopsis spp.
White snakeroot	Eupatorium rugosum Houtt.
Miscellaneous	
Blackberries	Rubus allegheniensis Porter
Buckwheat	
Knotweed	Polygonum spp.
Smartweed, Pennsylvania	Polygonum pennsylvanicum L.
Sorrel, red	Rumex acetosella L.
Cattails	Typha latifolia L.

TABLE D-1. (continued)

Fern and Fern Allies	
Club moss	*Lycopodium* spp.
Fern, bracken	*Pteridium aquilinum* (L.) Kuhn.
Fern, hartford	*Lygodium palmatum* (Bernh.) Swartz
Fireweed	*Epilobium angustifolium* L.
Fungi	
Puff ball	*Calvatia* spp.
Mushroom	*Amanita* spp.
Greenbrier	*Smilax rotundifolia* L.
Lichen	*Cladonia* spp.
Moss	*Polytrichum* spp. Roth
Pokeweed	*Phytolacca americana* L.
Sedge	
Nutsedge	*Cyperus* spp.
Bulrush	*Scirpus* spp.
Purslane, common	*Portulaca oleracea* L.
Whorled loosestrife	*Lysimachia quadrifolia* L.
Woody species	
Autumn olive	*Elaeagnus umbellata* Thunb.
Filbert	*Corylus americana* Walt.
Locust, black	*Robinia pseudoacacia* L.
Maple, red	*Acer rubrum* L.
Oak, sawtooth	*Quercus acutissima* Corruthers
Pine, loblolly	*Pinus taeda* L.
Pine, shortleaf	*Pinus echinata* Mill.
Pine, Virginia	*Pinus virginiana* Mill.
Shrub lespedeza	*Lespedeza bicolor* Turcz.
Sourwood	*Oxydendrum arboreum* (L.) DC.
Sumac, staghorn	*Rhus typhina* L.
Sweetgum	*Liquidambar styraciflua* L.
Yellow-poplar	*Liriodendron tulipifera* L.

TABLE D-2. OCCURRENCE, MEAN HEIGHT, AND PERCENT COMPOSITION OF GRASS SPECIES BY SECTORS FALL 1975

Species	Sector 1			Sector 2			Sector 3			Sector 4		
	Occurrence+ (pct)	Mean Ht. (cm)	Composition# (pct)	Occurrence (pct)	Mean Ht. (cm)	Composition (pct)	Occurrence (pct)	Mean Ht. (cm)	Composition (pct)	Occurrence (pct)	Mean Ht. (cm)	Composition (pct)
Broomsedge	12.1	50.2	2.7	7.2	52.3	3.3	13.1	31.5	11.6	6.0	41.8	2.7
Fescue, K-31	82.1	20.1	75.1	4.5	12.9	28.0	15.1	25.5	33.8	46.0	17.7	81.1
Lovegrass, weeping	7.1	24.1	3.3	4.2	15.6	40.7	5.0	25.5	6.3	-	-	-
Millet, foxtail	-	-	-	1.0	15.0	0.5	-	-	-	-	-	-
Millet, wild	-	-	-	-	-	-	1.0	60.0	2.1	-	-	-
Panicum	4.2	42.0	1.1	8.2	17.6	1.4	14.1	25.5	17.0	5.0	17.4	6.7
Ryegrass, perennial	0.7	20.0	0.1	-	-	-	-	-	-	-	-	-
Switchgrass	1.4	26.5	1.3	2.0	29.5	2.4	1.0	10.0	1.0	1.0	20.0	0.1

+ The number of plots on which a species occurred divided by the total number sampled.

Values represent the relationship of one herbaceous species to another with the total based on 100 percent in terms of existing cover.

*Less than one-tenth of one percent.

TABLE D-3. OCCURRENCE, MEAN HEIGHT, AND PERCENT COMPOSITION OF LEGUME SPECIES BY SECTORS FALL 1975

Species	Sector			Sector			Sector 3			Sector 4		
	Occurrence+ (pct)	Mean Ht. (cm)	Composition# (pct)	Occurrence (pct)	Mean Ht. (cm)	Composition (pct)	Occurrence (pct)	Mean Ht. (cm)	Composition (pct)	Occurrence (pct)	Mean Ht. (cm)	Composition (pct)
Clover, red	-	-	-	2	8.0	0.1	-	-	-	-	-	-
Kobe lespedeza	-	-	-	-	-	-	1.0	23.0	2.1	-	-	-
Korean lespedeza	2.8	15.25	0.9	5.1	15.6	3.3	-	-	-	-	-	-
Sericea lespedeza	25.0	88.5	11.0	34.0	19.8	7.3	5.0	19.8	0.8	-	-	-
Sicklepod	-	-	-	-	-	-	-	-	-	1.0	24.7	*

+ The number of plots on which a species occurred divided by the total number sampled.

Values represent the relationship of one herbaceous species to another with the total based on 100 percent in terms of existing cover.

*Less than one-tenth of one percent.

TABLE D-4. OCCURRENCE, MEAN HEIGHT, AND PERCENT COMPOSITION OF COMPOSITE SPECIES BY SECTORS FALL 1975

Species	Sector 1			Sector 2			Sector 3			Sector 4		
	Occurrence+ (pct)	Ht. (cm)	Composition# (pct)	Occurrence (pct)	Ht. (cm)	Composition (pct)	Occurrence (pct)	Ht. (cm)	Composition (pct)	Occurrence (pct)	Ht. (cm)	Composition (pct)
Aster, fall	2.1	53.3	0.6	3.1	23.0	0.5	4.0	29.8	0.8	3.0	65.7	0.9
Aster, white	0.7	18.0	0.1	3.1	40.0	0.2	1.0	23.0	*	1.0	30.0	1.3
Daisy, field	0.7	37.0	*	2.1	22.5	0.6	-	-	-	-	-	-
Dandelion	-	-	-	-	-	-	-	-	-	2.0	14.5	0.6
Fleabane	-	-	-	1.0	51.0	0.1	-	-	-	1.0	61.0	0.3
Goldenrod	0.7	61.0	0.1	-	91.0	0.1	-	-	-	-	-	-
Small ragwort	-	-	-	-	-	-	1.0	25.0	*	-	-	-
Tickseed	-	-	-	-	-	-	1.0	20.0	*	-	-	-
White snakeroot	-	-	-	-	-	-	1.0	10.0	*	-	-	-
Wild lettuce	0.7	1.0	*	-	-	-	-	-	-	1.0	13.0	*

+ The number of plots on which a species occurred divided by the total number sampled.

Values represent the relationship of one herbaceous species to another with the total based on 100 percent in terms of existing cover.

*Less than one-tenth of one percent.

TABLE D-5. OCCURRENCE, MEAN HEIGHT, AND PERCENT COMPOSITION OF MISCELLANEOUS SPECIES BY SECTORS FALL 1975

Species	Sector 1			Sector 2			Sector 3			Sector 4		
	Occurrence[+] (pct)	Mean Ht. (cm)	Composition[#] (pct)	Occurrence (pct)	Mean Ht. (cm)	Composition (pct)	Occurrence (pct)	Mean Ht. (cm)	Composition (pct)	Occurrence (pct)	Mean Ht. (cm)	Composition (pct)
Blackberries	0.7	30.0	*	5.1	38.8	1.9	1.0	15.0	0.6	-	-	-
Buckwheat												
Knotweed	-	-	-	-	-	-	1.0	5.0	3.3	-	-	-
Smartweed, Penn.	1.4	45.0	0.7	1.0	18.0	0.9	2.0	30.0	4.6	2.0	16.5	1.0
Sorrel, red	-	-	-	2.1	5.0	0.8	2.0	2.0	0.5	1.0	1.0	*
Cattails	2.1	87.0	0.9	3.1	34.0	3.9	1.0	23.0	2.1	1.0	122.0	1.0
Fern & Fern allies												
Club moss	-	-	-	-	-	-	1.0	1.0	0.2	-	-	-
Fern, bracken	-	-	-	-	-	-	1.0	13.0	0.5	-	-	-
Fern, hartford	-	-	-	-	-	-	2.0	15.0	0.5	-	-	-
Fireweed	-	-	-	1.0	25.0	*	4.0	25.8	4.1	-	-	-
Fungi												
Puffball	1.4	7.0	*	-	-	-	-	-	-	-	-	-
Mushroom	-	-	-	1.0	8.0	0.4	1.0	1.0	*	1.0	8.0	*
Greenbrier	2.1	17.0	0.1	3.1	19.3	0.1	6.1	21.0	1.7	-	-	-
Lichen, fructicose	1.4	0.5	0.2	1.0	1.0	0.2	1.0	1.0	*	-	-	-
Loosestrife, whorled	-	-	-	-	-	-	1.0	25.0	*	-	-	-
Moss	3.5	0.8	0.1	2.1	7.0	0.6	4.0	1.0	3.8	5.0	1.0	0.4
Pokeweed	0.7	152.0	0.1	1.0	76.0	*	-	-	-	2.0	25.5	2.0
Purslane, common	-	-	-	-	-	-	1.0	23.0	0.2	-	-	-
Sedges												
Nutsedge	1.4	5.5	0.1	4.1	5.2	1.4	1.0	3.0	*	2.0	13.0	0.6
Bulrush	2.1	131.7	1.5	3.1	77.3	1.3	1.0	5.0	2.4	1.0	122.0	1.3

+ The number of plots on which a species occurred divided by the total number sampled.
# Values represent the relationship of one herbaceous species to another with the total based on 100 percent in terms of existing cover.
* Less than one-tenth of one percent.

APPENDIX E

(Supplemental information on water quality)

TABLE E-1 COMPARISON OF WATER QUALITY PARAMETERS COLLECTED AT THOMPSON CREEK MILE 0.01 DURING MINING AND CONVENTIONAL RECLAMATION AND DURING REMEDIAL TREATMENT

Date	Water Temp. °C	Turbidity JTU	pH	Total Alkalinity $CaCo_3$ mg/l	Total Acidity $CaCo_3$ mg/l	Sulfate SO_4 mg/l	Iron Fe mg/l	Manganese Mn mg/l	Total Hardness mg/l
During Mining and Conventional Reclamation*									
02/10/71	0.3	5	5.0	-	21	65	0.33	6.30	31
03/09/71	2.8	3	5.2	2	16	45	0.25	1.80	27
04/13/71	11.7	4	4.6	-	11	35	0.16	4.00	24
05/03/71	11.5	5	5.3	2	13	50	0.52	5.90	32
06/07/71	21.1	1	5.4	3	21	120	0.21	1.20	67
07/07/71	21.7	2	4.5	0	20	-	0.31	8.10	58
08/10/71	18.6	1	4.7	-	20	100	0.33	12.00	82
09/08/71	16.9	2	4.6	-	18	110	0.32	9.30	66
11/02/71	15.0	10	4.4	-	22	110	1.30	13.00	86
12/01/71	5.0	1	4.9	-	18	90	0.24	9.90	68
02/09/71	-	-	4.0	-	-	-	-	-	-
04/18/72	10.8	5	3.7	0	46	180	1.50	31.00	190
07/25/72	21.4	1	3.6	0	65	230	0.61	28.00	180
10/25/72	10.8	1	3.8	0	33	120	0.63	14.00	87
During Remedial Treatment									
10/30/75	-	<1	3.8	0	120	98	0.15	1.90	-
11/20/75	9.5	6	5.0	0	17	77	3.10	1.50	-
12/18/75	-	1	5.6	0	11	52	0.13	1.00	-
01/21/76	1	<1	4.7	0	-	62	0.23	1.50	-
02/18/76	5	14	4.3	0	-	100	1.40	2.40	-
03/16/76	7.2	1	4.8	0	-	65	0.32	1.60	-
04/07/76	11.7	<1	4.5	0	-	69	0.28	1.70	-
05/19/76	13.3	-	4.7	0	-	-	-	-	-
06/15/76	20.0	-	4.5	0	-	-	-	-	-

*Four months of late 1970 data also available.

TABLE E-2. COMPARISON OF WATER QUALITY PARAMETERS COLLECTED AT YELLOW BRANCH MILE 0.13 DURING MINING AND CONVENTIONAL RECLAMATION AND BEFORE AND DURING REMEDIAL TREATMENT

Date	Water Temp. °C	Turbidity JTU	pH	Total Alkalinity $CaCo_3$ mg/l	Total Acidity $CaCo_3$ mg/l	Sulfate SO_4 mg/l	Iron Fe mg/l	Manganese Mn mg/l	Total Hardness mg/l	Cond. 25C Micromho
During Mining and Conventional Reclamation										
02/10/71	.0	20	6.6	7	4	45	1.10	0.24	39	-
03/09/71	5.0	10	6.7	8	4	35	0.52	0.06	26	-
04/13/71	13.6	10	6.2	5	3	35	0.68	0.26	34	120
05/03/71	11.8	20	7.4	12	1	30	1.00	0.08	26	80
06/07/71	21.4	20	7.2	20	5	140	1.70	0.14	92	260
07/07/71	21.9	20	6.7	31	4	-	2.80	0.21	99	-
08/09/71	21.1	70	7.2	24	4	60	3.20	0.38	77	-
09/08/71	16.7	100	5.0	-	19	130	4.80	1.20	110	-
10/04/71	18.3	50	6.5	23	15	100	3.00	0.80	110	-
11/02/71	17.0	20	6.6	9	8	75	2.00	2.50	150	-
12/01/71	5.0	10	6.9	26	7	90	1.10	1.30	90	-
02/09/72	-	-	6.0	-	-	-	-	-	-	-
04/18/72	13.9	30	6.7	7	5	80	2.80	1.90	110	240
05/23/72	-	-	6.6	-	-	-	-	-	-	-
07/25/72	21.7	20	6.8	20	-	200	1.80	4.60	220	460
10/25/72	10.8	15	6.4	12	5	160	1.50	5.40	150	350
Before Remedial Treatment										
08/25/75	23.3	37	5.3	5	13	320	3.00	14.00	-	-
09/17/75	15.6	400	5.4	-	82	220	25.00	16.00	-	-
10/30/75	12.5	2	4.7	0	90	160	1.30	7.70	-	-
During Remedial Treatment										
11/11/75	10.0	22	5.7	12	6	210	3.00	6.20	-	-
12/18/75	4.0	8	6.9	11	6	32	2.30	3.50	-	-
01/21/76	-	-	6.4	11	-	180	3.00	8.00	-	-
02/18/76	10.0	3,000	5.0	0	-	180	14.00	5.80	-	-
03/16/76	7.2	30	6.6	7	-	160	2.30	-	-	-
04/07/76	13.9	27	6.0	6	-	180	2.10	-	-	-
05/19/76	12.8	-	6.2	6	-	-	-	-	-	-
06/15/76	20.6	-	6.1	8	-	-	-	-	-	-

TABLE E-3. COMPARISON OF WATER QUALITY PARAMETERS COLLECTED AT OLLIS CREEK (STATION 1) DURING MINING AND CONVENTIONAL RECLAMATION, AFTER PARTIAL TREATMENT, AND DURING REMEDIAL TREATMENT

Date	Water Temp.°C	Turbidity JTU	pH	Total Alkalinity $CaCO_3$ mg/l	Total Acidity $CaCO_3$ mg/l	Sulfate SO_4 mg/l	Iron Fe mg/l	Manganese Mn mg/l	Total Hardness mg/l	Cond. 25C Micromho
During Mining and Conventional Reclamation										
02/10/71	3.0	10	5.8	2	5	25	0.25	0.56	15	-
03/09/71	5.5	9	5.8	2	6	35	0.28	0.45	20	-
04/13/71	14.0	3	6.0	2	4	23	0.23	0.42	18	65
05/03/71	13.0	3	7.6	7	<1	25	0.41	0.40	21	100
06/08/71	23.3	6	6.8	5	3	24	0.48	0.35	24	80
07/07/71	24.4	5	6.2	9	5	-	0.55	0.56	41	-
08/09/71	23.3	5	6.3	6	3	40	0.29	0.71	35	-
09/08/71	23.3	9	6.7	6	2	40	0.47	0.41	46	-
10/04/71	22.5	1	4.9	-	13	95	0.37	1.90	74	-
11/02/71	18.0	7	6.0	3	4	70	0.46	1.80	80	-
12/01/71	6.0	4	6.9	14	4	80	0.31	1.40	71	-
02/09/72	-	-	5.0	-	-	-	-	-	-	-
04/18/72	15.6	5	5.5	3	6	27	0.29	0.85	42	110
05/23/72	-	-	5.3	-	-	-	-	-	-	-
07/25/72	26.1	1	5.5	2	8	120	0.22	2.80	46	260
10/25/72	12.8	5	4.5	0	16	100	0.70	2.90	86	230
After Limited Remedial Treatment										
07/21/75	-	3	-	-	-	42	0.86	0.98	-	-
08/25/75	21.7	2	5.4	28	32	56	0.32	0.10	-	-
09/17/75	16.1	1	7.0	31	22	40	0.08	0.05	-	-
10/30/75	14.0	<1	4.5	0	70	56	0.16	1.30	-	-
During Remedial Treatment										
11/20/75	9.0	1	6.8	1	3	62	0.14	1.00	-	-
12/18/75	4.0	2	6.2	<1	2	54	0.32	1.40	-	-
01/21/76	-	-	5.4	1	-	-	-	-	-	-
02/18/76	8.9	2	5.4	1	-	60	0.78	1.40	-	-
03/16/76	10.0	2	5.2	1	-	57	0.28	1.20	-	-
04/07/76	11.7	2	5.2	<1	-	43	0.43	0.74	-	-
05/19/76	13.9	-	5.1	0	-	-	-	-	-	-
06/15/76	21.7	-	5.8	4	-	-	-	-	-	-

TABLE E-4. WATER QUALITY PARAMETERS COLLECTED AT LAUREL BRANCH BEFORE REMEDIAL TREATMENT

Date	Water Temp. °C	Turbidity JTU	pH	Total Alkalin. mg/l	Total Acidity mg/l	Sulfate mg/l	Iron mg/l	Man-ganese mg/l	Susp. Solids mg/l
Before Remedial Treatment									
08-25-75	22.8	10	5.1	2	10	220	.7	4.1	10
09-17-75	15.6	44	5.9	4	36	130	2.0	3.5	36
10-30-75	12.0	150	4.2	0	7	59	.4	1.8	1
11-20-75	9.0	4	6.0	<1	23	72	1.0	1.2	23
12-18-75	4.0	2	6.8	2	12	62	.4	.7	12
01-21-76	-	5	5.8	2	2	42	.6	1.2	-
02-18-76	10.0	120	5.4	1	5	77	5.0	1.9	-
03-16-76	7.2	7	6.0	2	2	45	.6	.9	-
04-07-76	10.0	7	5.4	1	7	59	.6	1.3	-
05-19-76	-	30	5.9	2	3	40	.8	1.0	-
06-15-76	20.6	4	5.8	3	1	92	.5	2.6	-

TABLE E-5. WATER QUALITY PARAMETERS COLLECTED AT AN UNNAMED TRIBUTARY TO OLLIS CREEK BEFORE AND DURING REMEDIAL TREATMENT

Date	Water Temp. °C	Turbidity JTU	pH	Total Alkalin. mg/1	Total Acidity mg/1	Sulfate mg/1	Iron mg/1	Man-ganese mg/1	Susp. Solids mg/1
Before Remedial Treatment									
10-30-75	14.4	7	3.4	0	150	600	4.0	23	3
During Remedial Treatment									
11-20-75	11.5	14	5.4	11	36	790	12.0	2.0	34
12-18-75	4.0	9	6.6	8	26	440	12.0	16.0	25
01-21-76	-	14	5.8	2	28	420	9.4	14.0	-
02-18-76	10.6	7000	4.7	0	46	210	29.0	10.0	-
03-16-76	7.2	21	6.1	2	26	250	8.6	12.0	-
04-07-76	18.9	28	5.0	0	27	400	5.4	8.5	-
05-19-76	13.3	12	5.3	1	18	310	4.7	10.0	-
06-15-76	20.0	5	5.3	2	18	540	3.9	12.0	-

APPENDIX F

(Supplemental information on aquatic invertebrates)

TABLE F-1. TAXA OF BENTHIC INVERTEBRATES COLLECTED BY ALL METHODS DURING STRIPPING, AFTER PARTIAL REMEDIAL TREATMENT, AND DURING REMEDIAL TREATMENT IN OLLIS CREEK AND ITS TRIBUTARIES

	During Stripping 1970-71	After partial Rem. Trmt.* Aug.-Oct. 1975	During Rem. Trmt. Nov. 1975-July 1976
Platyhelminthes			
Planariidae	X	X	X
Nematomorpha	X		X
Nematoda		X	
Annelida			
Oligochaeta	X	X	X
Arthropoda			
Crustacea			
Lirceus	X	X	X
Ascellus			X
Hyalella	X		
Cambarus bartonii	X	X	X
Insecta			
Collembola		X	X
Plecoptera			
Peltoperla	X	X	X
Brachyptera		X	X
Taeniopteryx	X		
Nemoura	X		X
Leuctra			X
Paraleuctra	X		
Isoperla	X		
Chloroperla			X
Acroneuria	X	X	
Ephemeroptera			
Ephemera	X	X	X
Caenis	X		
Pseudocleon	X		
Neocleon	X		
Centroptilum	X		
Baetis	X	X	
Ephemerella	X		X
Ameletus	X		
Isonychia		X	
Paraleptophlebia	X	X	

TABLE F-1. (continued)

	During Stripping 1970-71	After partial Rem. Trmt.* Aug.-Oct. 1975	During Rem. Trmt. Nov. 1975-July 1976
Leptophlebia			X
Cinygma	X		
Stenonema	X	X	X
Epeorus	X		X
Odonata			
Micromia	X		
Tetragoneuria	X		
Libellulidae	X		
Boyeria	X	X	X
Cordulegaster			X
Ophiogomphus	X		
Gomphus	X		
Aeschna	X	X	X
Agrion	X		X
Argia	X		
Anax			X
Ischnura	X		
Coenagrion	X		
Hemiptera			
Gerris	X	X	X
Microvelia		X	
Rhagovelia	X	X	X
Notonecta	X		
Gyrinus			X
Corixidae	X	X	X
Megaloptera			
Sialis	X	X	X
Nigronia	X	X	X
Corydalus	X	X	X
Chauloides			X
Trichoptera			
Rhyacophilia			X
Hydropsyche	X	X	X
Cheumatopsyche	X	X	X
Diplectrona	X	X	X
Chimarra	X	X	
Trentonius			X
Polycentropus	X	X	X
Mystacides	X		
Lepidostoma			X
Ptilostomis			X
Neophylax	X		

TABLE F-1. (continued)

	During Stripping 1970-71	After partial Rem. Trmt.* Aug.-Oct. 1975	During Rem. Trmt. Nov. 1975-July 1976
Pycnopsyche	X		X
Limnophila			X
Diptera			
Chronomidae	X	X	X
Simulidae			X
Simulium	X	X	X
Heleidae	X		
Palpomyia		X	X
Tipula	X	X	X
Pedicia	X	X	X
Hexatoma	X	X	X
Eriocera		X	X
Antocha	X		
Limnophila	X		
Pilaria	X		
Chrysops	X		
Atherix	X		
Tabanus	X		X
Dixa	X		
Adelphomyia	X		
Coleoptra			
Psephenus	X		
Ectoparia	X		
Elmidae		X	
Stenelmis	X		
Optioservus	X		
Dryopidae		X	
Helichus	X		
Dineutus	X		
Bidessus	X		
Helophorus	X		
Empididae		X	
Dytiscidae		X	
Hydrophilidae		X	
Hydraenidae			
Mollusca			
Psidium	X		X
Total Number of Taxa	71	40	49

*Ollis Creek and Thompson Creek received some remedial treatment in fall 1974 and spring 1975.

TABLE F-2. COMPARISON OF ABUNDANCE OF AQUATIC INVERTEBRATES BEFORE AND DURING RECLAMATION ON STREAMS ON THE OLLIS CREEK WATERSHED

	After Limited Remedial Treatment* No. Per Sq. Foot		During Remedial Treatment+ No. Per Sq. Foot	
	Mean	Range++	Mean	Range
Ollis Creek Mile 0.78	20.25	4.25 - 45.50	4.00	1.50 - 14.00
Ollis Creek Mile 1.3	14.90	0.75 - 25.00	2.75	0.25 - 7.00
Ollis Creek Mile 3.37	14.90	2.75 - 31.75	2.60	1.00 - 4.50
Ollis Creek Mile 4.15	10.00	2.75 - 22.50	3.40	0.25 11.25
Laurel Branch#	3.10	1.00 - 6.00	3.10	0.25 7.00
Yellow Branch	10.75	7.25 - 22.25	3.60	0.75 - 8.50
Unnamed Tributary	1.40	1.25 - 1.50	1.00	0 - 2.50
Thompson Creek##	1.50	1.50	8.50	2.00 - 35.50

*August - October, 1975
+November, December, 1975; January - July 1976
++Ranges of mean of four samples per month.
#No reclamation yet performed.
##Only one month sampled after limited remedial treatment.

TABLE F-3. MEAN NUMBERS OF AQUATIC INVERTEBRATES COLLECTED IN SQUARE FOOT SURBER SAMPLES AT OLLIS CREEK, STATION 1, DURING 1975-1976. VALUES REPRESENT MEANS OF FOUR SAMPLES EACH MONTH

	After Limited Remedial Treatment			During Remedial Treatment								
	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July
Nematomorpha	-	-	-	-	-	-	0.25	-	-	-	-	-
Annelida												
Oligochaeta	-	-	-	0.25	-	3.00	1.50	0.50	-	-	0.25	-
Arthropoda												
Asellus	-	-	-	-	-	-	0.25	-	-	-	-	-
Cambarus bartonii	0.50	0.50	0.25	-	-	-	-	1.50	0.50	-	0.25	0.50
Insecta												
Plecoptera												
Brachyptera	1.75	-	-	0.25	-	-	-	-	-	-	-	-
Leuctra	-	-	-	-	-	0.25	-	-	-	-	-	0.25
Acroneuria	0.25	-	-	-	-	-	-	-	-	-	-	-
Ephemeroptera												
Stenonema	2.00	2.50	1.75	0.25	-	-	-	-	-	-	-	-
Epeorus	-	-	-	-	-	-	-	-	-	-	-	0.25
Isonychia	0.50	-	-	-	-	-	-	-	-	-	-	-
Baetis	11.50	2.00	-	-	-	-	-	-	-	-	-	-
Odonata												
Boyeria	0.25	0.25	-	-	-	-	-	-	-	-	-	-
Hemiptera												
Gerris	1.25	-	-	-	-	-	0.50	-	-	-	-	-
Microvelia	-	0.75	-	-	-	-	-	-	-	-	-	-
Rhagovelia	-	0.75	-	-	-	-	-	-	-	-	-	-
Megaloptera												
Sialis	-	-	-	-	-	-	-	-	-	-	-	0.25
Nigronia	2.50	0.50	-	0.25	-	-	-	-	-	0.25	0.25	-
Trichoptera												
Hydropsyche	12.25	-	0.25	-	-	-	-	-	-	-	1.25	6.00
Cheumatopsyche	1.50	-	-	-	-	-	-	-	-	-	0.75	-
Chimarra	6.00	-	-	-	-	-	-	-	-	-	-	-
Polycentropus	1.25	0.50	1.50	-	-	-	-	0.25	-	-	-	-
Rhyacophila	-	-	-	-	-	-	-	-	-	-	-	0.25
Diptera												
Chironomidae	2.50	3.00	0.50	0.50	-	0.50	0.50	0.50	2.25	0.50	1.75	0.50

TABLE F-3. (continued)

	After Limited Remedial Treatment			During Remedial Treatment								
	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July
Simulidae	-	-	-	-	-	-	-	-	-	0.50	0.25	-
Simulium	0.50	-	-	-	-	-	-	-	-	-	-	6.00
Heleidae	-	-	-	-	-	0.25	-	-	-	0.25	-	-
Palpomyia	-	0.25	-	-	-	-	-	-	-	-	-	-
Pedicia	-	-	-	-	-	0.50	-	-	-	-	-	-
Tipula	-	-	-	-	-	-	-	-	0.25	-	-	-
Coleoptera												
Dryopidae	1.00	-	-	-	-	-	-	-	-	-	-	-
Hydrophilidae	-	-	0.25	-	-	-	-	-	-	-	-	-
Elmidae												
Stenelmis	-	-	-	-	-	-	-	-	-	-	0.25	-
Mollusca												
Sphaeriidae	-	-	-	-	-	-	0.25	-	-	-	-	-
Mean Number of Organisms	45.50	11.00	4.25	1.50	-	4.50	3.25	2.75	3.00	1.50	5.00	14.25
Grand Mean	-	20.25	-	-	-	-	-	4.00	-	-	-	-

TABLE F-4. MEAN NUMBERS OF AQUATIC INVERTEBRATES COLLECTED IN SQUARE FOOT SURBER SAMPLES AT OLLIS CREEK, STATION 2, DURING 1975-1976. VALUES REPRESENT MEANS OF FOUR SAMPLES EACH MONTH

	After Limited Remedial Treatment			During Remedial Treatment								
	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July
Nematoda	5.50	-	-	-	-	-	-	-	-	-	-	-
Annelida												
Oligochaeta	-	0.50	-	-	-	2.00	5.50	-	0.25	-	-	0.25
Arthropoda												
Lirceus	-	-	-	-	-	-	-	-	-	0.25	-	-
Cambarus bartonii	-	-	-	-	-	-	0.25	-	-	0.25	-	0.25
Insecta												
Collembola	-	-	-	0.25	-	-	-	-	-	-	-	-
Plecoptera												
Peltoperla	-	0.25	-	-	-	-	-	-	0.25	0.25	-	-
Brachyptera	0.75	0.50	0.25	-	0.25	-	-	-	-	-	-	-
Leuctra	-	-	-	-	-	0.25	-	-	0.25	-	-	0.25
Acroneuria	-	0.25	-	-	-	-	-	-	-	-	-	-
Ephemeroptera												
Isonychia	1.50	0.25	-	-	-	-	-	-	-	-	-	-
Baetis	4.75	6.00	-	-	-	-	-	-	-	-	-	-
Odonata												
Agrion	-	-	-	-	-	-	-	0.25	-	-	-	-
Megaloptera												
Sialis	-	-	-	-	-	-	0.25	-	-	-	-	-
Nigronia	0.50	0.50	0.25	-	-	-	-	-	-	-	-	0.25
Corydalus	0.50	0.25	-	-	-	-	-	-	-	-	-	0.25
Trichoptera												
Hydropsyche	6.50	3.00	-	-	0.25	-	-	-	-	-	-	1.00
Cheumatopsyche	0.25	1.75	-	-	-	0.50	-	-	-	-	-	-
Diplectrona	-	-	-	-	-	-	-	-	-	-	-	0.25
Polycentropus	0.25	-	-	-	-	-	-	-	-	-	-	-
Ptilostomis	-	-	-	-	0.25	-	-	-	-	-	-	-
Chimarra	-	0.25	-	-	-	-	-	-	-	-	-	-
Pycnopsyche	-	-	-	-	-	0.25	-	-	-	-	-	-
Chironomidae	1.50	2.50	0.25	-	0.25	3.50	0.25	0.25	-	0.50	2.75	-
Simulidae	-	-	-	-	-	-	-	-	-	-	-	0.75
Simulium	2.50	2.00	-	-	-	-	-	-	-	-	-	-
Palpomyia	-	-	-	-	-	0.25	-	-	-	-	0.25	-
Tipula	-	-	-	-	-	0.25	0.25	-	-	-	-	-

TABLE F-4. (continued)

	After Limited Remedial Treatment			During Remedial Treatment								
	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July
Antocha	-	-	-	-	-	-	0.25	-	-	-	-	-
Eriocera	-	-	-	-	-	-	0.25	-	-	-	-	-
Coleoptera												
Dryopidae	0.25	-	-	-	-	-	-	-	-	-	-	-
Dytiscidae	-	-	-	-	-	-	-	0.25	-	-	-	-
Hydrophilidae	-	0.25	-	-	-	-	-	-	-	-	-	-
Empididae	-	0.25	-	-	-	-	-	-	-	-	-	-
Elmidae	0.25	0.50	-	-	-	-	-	-	-	-	-	-
Mean Number of Organisms	25.00	19.00	0.75	0.25	1.00	7.75	7.00	0.75	0.75	1.25	3.00	3.25
Grand Mean	-	14.90	-	-	-	-	-	2.75	-	-	-	-

TABLE F-5. MEAN NUMBERS OF AQUATIC INVERTEBRATES COLLECTED IN SQUARE FOOT SURBER SAMPLES AT OLLIS CREEK, STATION 3, DURING 1975-1976. VALUES REPRESENT MEANS OF FOUR SAMPLES PER MONTH

	After Limited Remedial Treatment			During Remedial Treatment								
	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July
Platyhelminthes												
Planariidae	-	-	-	0.25	-	-	1.50	0.25	-	-	1.25	-
Annelida												
Oligochaeta	-	-	-	-	-	-	0.50	-	0.25	-	-	-
Arthropoda												
Cambarus bartonii	0.25	-	0.25	-	-	-	-	-	-	-	-	-
Insecta												
Collembola												
Pleloptera												
Brachyptera	-	-	0.25	-	-	-	-	-	-	-	-	-
Ephemeroptera												
Baetis	0.50	-	-	-	-	-	-	-	-	-	-	-
Odonata												
Boyeria	-	-	-	-	-	-	-	-	-	-	-	0.25
Agrion	-	-	-	0.50	-	-	-	-	-	-	-	-
Hemiptera												
Gerris	-	-	0.25	-	-	-	-	-	-	-	-	-
Megaloptera												
Corydalus	0.25	-	-	-	-	-	-	-	-	-	-	-
Sialis	-	-	-	-	-	-	-	-	0.25	0.25	-	-
Trichoptera												
Hydropsyche	29.50	3.00	1.25	1.50	0.50	0.50	-	-	1.25	-	-	0.50
Cheumatopsyche	-	-	-	-	-	-	-	0.25	-	-	-	-
Polycentropus	1.00	0.25	0.25	0.50	0.25	0.25	-	0.50	0.25	0.25	1.25	0.75
Pycnopsyche	-	-	-	-	-	-	0.25	-	0.25	-	-	-
Diptera												
Chironomidae	-	6.50	0.25	0.25	-	-	-	-	0.50	0.25	1.25	0.50
Simulidae												
Simulium	0.25	0.50	-	-	-	-	-	-	-	-	-	-
Palpomyia	-	-	-	-	-	-	-	-	-	-	-	0.25
Eriocera	-	-	-	0.25	-	-	-	-	-	-	-	-
Tipula												
Coleoptera												
Gyrinus	-	-	-	-	-	-	0.25	-	0.50	0.25	-	-
Mean Number of Organisms	31.75	10.25	2.75	4.50	4.00	1.25	4.50	1.25	3.75	1.00	3.75	2.25
Grand Mean	-	14.90	-	-	-	-	-	2.60	-	-	-	-

TABLE F-6. MEAN NUMBERS OF AQUATIC INVERTEBRATES COLLECTED IN SQUARE FOOT SURBER SAMPLES AT LAUREL BRANCH DURING 1975-1976. VALUES REPRESENT MEANS OF FOUR SAMPLES EACH MONTH

	Before Remedial Treatment											
	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July
Platyhelminthes												
Planariidae	-	-	-	0.25	-	-	-	-	-	-	-	-
Nematoda	0.75	0.25	-	-	-	-	-	-	-	-	-	-
Annelida												
Oligochaeta	-	1.50	-	-	1.00	0.25	5.75	0.25	0.25	2.00	1.50	-
Arthropoda												
Lirceus	-	-	-	-	-	-	-	-	0.25	-	-	-
Cambarus bartonii	-	1.25	-	-	0.25	-	-	1.25	-	-	2.00	-
Insecta												
Collembola	0.25	-	-	-	-	-	-	-	-	-	-	-
Plecoptera												
Peltoperla	0.25	-	-	-	-	-	-	-	-	-	-	-
Brachyptera	0.25	-	0.25	0.50	0.50	-	-	-	-	-	-	-
Nemoura	-	-	-	-	0.75	-	-	-	-	-	-	-
Leuctra	-	-	-	-	-	0.25	-	0.25	-	-	-	-
Chloroperla	-	-	-	-	-	-	-	0.25	-	-	-	-
Acroneuria	-	0.50	-	-	-	-	-	-	-	-	-	-
Ephemeroptera												
Ephemera	-	0.25	-	-	-	-	-	-	-	-	-	0.25
Ephemerella	-	-	-	-	-	-	-	-	0.25	0.25	-	-
Leptophlebia	-	-	-	-	-	0.25	-	-	-	-	-	-
Hemiptera												
Gerris	-	0.15	-	-	-	-	-	-	-	-	-	-
Rhagovelia	-	0.15	-	-	-	-	-	-	-	-	-	-
Megaloptera												
Sialis	1.00	-	-	-	-	-	-	-	-	0.25	0.50	-
Nigronia	1.75	-	-	-	-	-	-	-	-	-	0.25	-
Trichoptera												
Hydropsyche	1.00	0.25	-	-	-	-	-	-	-	-	-	-
Cheumatopsyche	2.00	-	-	-	-	-	-	-	-	-	-	-
Polycentropus	0.25	-	-	-	-	0.25	-	-	-	-	-	-
Pycnopsyche	-	-	-	-	0.50	0.25	0.25	0.25	-	-	-	-
Limnephila	-	-	-	-	-	-	-	-	-	0.25	-	-

TABLE F-6. (continued)

	Before Remedial Treatment											
	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July
Diptera												
Chironomidae	1.40	0.75	0.75	-	-	-	-	-	0.50	-	2.00	-
Heleidae	0.25	-	-	-	-	-	-	0.25	-	-	-	-
Palpomyia	-	0.25	-	-	-	-	-	-	-	-	-	-
Eriocera	-	0.25	-	-	-	-	-	-	-	0.25	-	-
Hexatoma	-	-	-	-	-	-	0.25	-	-	-	0.25	-
Tipula	-	-	-	-	0.25	-	0.50	-	-	0.25	-	-
Coleoptera												
Dryopidae	-	0.25	-	-	-	-	-	-	-	0.25	-	-
Dytiscidae	-	-	-	-	-	-	-	-	-	-	0.50	-
Hydrophilidae	-	-	-	-	0.25	-	-	-	-	-	-	-
Empididae	0.50	-	-	-	-	-	-	-	-	-	-	-
Elmidae	0.25	-	-	-	-	-	-	-	-	-	-	-
Mean Number of Organisms	2.25	6.00	1.00	0.75	3.50	1.75	6.75	2.50	1.75	3.50	7.00	0.25
Grand Mean	-	3.10	-	-	-	-	-	3.10	-	-	-	-

TABLE F-7. MEAN NUMBER OF AQUATIC INVERTEBRATES COLLECTED IN SQUARE FOOT SURBER SAMPLES AT YELLOW BRANCH DURING 1975-1976. VALUES REPRESENT MEANS OF FOUR SAMPLES PER MONTH

	Before Remedial Treatment			During Remedial Treatment								
	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July
Platyhelminthes												
Planariidae	-	0.25	-	-	-	-	-	-	-	-	-	-
Annelida												
Oligochaeta	-	-	-	2.0	-	0.25	-	0.25	-	-	0.75	-
Arthropoda												
Cambarus bartonii	0.25	-	-	-	-	-	-	-	-	-	0.50	-
Insecta												
Collembola	-	-	-	-	-	-	-	-	-	-	0.25	-
Plecoptera												
Peltoperla	0.25	0.25	-	0.25	0.25	-	0.25	-	0.25	-	-	-
Brachyptera	-	-	-	0.75	-	-	-	-	-	-	-	-
Nemoura	-	-	-	-	0.25	-	-	-	-	-	-	-
Leuctra	-	-	-	-	-	-	-	-	-	-	0.25	-
Hemiptera												
Corixidae	-	0.75	-	-	-	-	-	-	-	-	-	-
Gerris	-	0.25	-	-	-	-	-	-	-	-	-	-
Megaloptera												
Sialis	0.25	-	0.25	-	-	0.75	-	0.25	-	-	-	-
Chauloides	-	-	-	-	-	-	-	-	-	0.50	-	-
Trichoptera												
Hydropsyche	3.00	0.25	0.25	-	0.25	-	-	-	-	-	-	2.00
Cheumatopsyche	-	0.25	0.50	-	-	0.50	-	0.50	-	-	-	-
Diplectrona	-	-	-	-	-	-	-	-	-	-	0.50	1.75
Pycnopsyche	-	-	-	-	-	-	0.25	-	-	-	-	-
Chimarra	-	0.25	-	-	-	-	-	-	-	-	-	-
Diptera												
Chironomidae	2.00	19.25	0.50	2.75	-	0.75	0.75	1.50	0.25	-	-	0.25
Simulidae	-	-	-	-	-	0.25	-	-	-	-	-	-
Heleidae	-	-	-	-	-	-	-	-	-	0.25	-	-
Eriocera	-	-	-	-	-	-	-	0.25	-	-	-	-
Hexatoma	1.50	0.50	-	0.25	-	-	-	-	-	-	-	-
Pedicia	-	-	-	-	-	0.25	-	-	-	-	-	-
Tipula	-	-	1.25	2.50	1.75	2.50	1.25	2.00	1.25	-	-	0.25
Coleoptera												
Dryopidae	-	0.25	-	-	-	-	-	-	-	-	-	-
Dytiscidae	-	-	-	-	-	-	-	-	-	-	0.25	-
Mean Number of Organisms	7.25	22.25	2.75	8.50	2.50	5.25	2.50	4.75	1.75	0.75	2.50	3.75
Grand Mean	-	10.75	-	-	-	-	-	3.60	-	-	-	-

TABLE F-8. MEAN NUMBERS OF AQUATIC INVERTEBRATES COLLECTED IN SQUARE FOOT SURBER SAMPLES AT OLLIS CREEK STATION 6, DURING 1975-1976. MEAN VALUES REPRESENT MEANS OF FOUR SAMPLES PER MONTH

	After Limited Remedial Treatment			During Remedial Treatment								
	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July
Annelida												
Oligochaeta	-	-	-	0.25	-	-	0.25	-	0.25	-	-	-
Arthropoda												
Cambarus bartonii	0.50	-	-	-	-	-	-	0.25	-	-	-	-
Insecta												
Pleloptera												
Peltoperla	-	-	-	-	-	-	-	-	-	0.50	-	-
Brachyptera	1.25	0.50	-	0.5	-	-	-	-	0.75	-	-	-
Leuctra	-	-	-	-	-	0.25	0.25	0.25	-	-	1.25	1.00
Acroneuria	-	0.75	-	-	0.25	-	-	-	-	-	-	-
Hemiptera												
Gerris	0.75	-	-	-	-	-	-	-	-	-	-	-
Microvelia	1.00	-	-	-	-	-	-	-	-	-	-	-
Megaloptera												
Sialis	-	0.25	1.00	-	-	1.00	-	0.25	-	0.25	0.25	-
Nigronia	-	0.75	-	-	-	-	0.25	-	-	-	-	0.75
Trichoptera												
Hydropsyche	0.25	0.25	0.25	0.25	-	-	-	-	-	-	-	0.75
Cheumatopsyche	-	6.75	-	0.50	-	-	0.75	-	0.75	-	-	-
Diplectrona	0.50	-	-	-	-	-	-	-	-	-	-	2.0
Polycentropus	-	1.25	0.25	-	-	-	-	-	-	-	-	-
Pycnopsyche	-	-	-	0.25	-	-	-	0.25	-	-	-	-
Diptera												
Chironomidae	0.50	9.00	0.75	-	-	-	0.25	-	0.25	-	8.75	4.50
Heleidae	-	2.75	-	-	-	-	-	-	-	-	-	-
Palpomyia	-	-	-	0.25	-	-	-	-	-	-	0.25	-
Hexatoma	-	-	0.25	-	-	-	-	-	-	-	-	-
Pedicia	-	-	-	-	-	-	-	-	-	-	0.25	-
Tipula	-	-	0.25	0.75	-	-	0.25	-	-	-	-	0.25
Coleoptera												
Dryopidae	-	-	-	-	-	-	-	0.25	-	-	-	-
Dytiscidae	-	-	-	-	-	-	-	-	0.25	-	-	-
Hydrophilidae	-	0.25	-	-	-	-	-	-	-	-	-	-
Mean Number of Organisms	4.75	22.50	2.75	2.75	0.25	1.25	2.00	1.25	2.25	0.75	11.25	9.25
Grand Mean	-	10.00	-	-	-	-	-	3.40	-	-	-	-

TABLE F-9. MEAN NUMBERS OF AQUATIC INVERTEBRATES COLLECTED IN SQUARE FOOT SURBER SAMPLES AT UNNAMED TRIBUTARY OF OLLIS CREEK 1975-1976. VALUES REPRESENT MEANS OF FOUR SAMPLES PER MONTH

	Before Remedial Treatment			During Remedial Treatment								
	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July
Annelida												
Oligochaeta	-	-	-	0.25	-	-	-	-	-	-	-	-
Arthropoda												
Insecta												
Collembola	0.25	-	-	-	-	-	-	-	-	-	-	-
Plecoptera												
Peltoperla	-	-	-	-	0.25	-	-	-	-	-	-	-
Brachyptera	-	0.75	-	-	-	-	-	-	-	-	-	-
Leuctra	-	-	-	-	-	-	-	-	-	-	0.25	-
Ephemeroptera												
Epeorus	-	-	-	-	-	-	-	-	-	-	0.25	-
Hemiptera												
Corixidae	-	-	-	0.25	-	-	-	-	-	-	-	-
Megaloptera												
Sialis	0.25	-	0.25	0.75	-	0.25	-	-	-	-	-	-
Nigronia	-	-	-	-	-	0.25	-	0.25	-	-	-	0.25
Trichoptera												
Cheumatopsyche	-	-	-	-	-	-	-	-	-	-	-	0.25
Trentonius	-	-	-	-	-	-	-	-	-	-	0.25	-
Polycentropus	-	-	-	0.25	-	-	-	-	-	-	-	-
Diptera												
Chironomidae	1.00	0.25	0.25	0.25	-	0.25	0.75	0.25	0.25	-	1.25	-
Simulium	-	-	0.25	-	-	-	-	-	-	-	-	-
Heleidae	-	0.25	-	-	-	-	-	-	-	-	-	-
Hexatoma	-	-	0.50	-	-	-	-	-	-	-	-	-
Pedicia	-	0.25	-	-	-	-	-	-	-	-	-	-
Tipula	-	-	-	0.25	-	-	-	0.25	0.25	-	0.25	-
Tabanus	-	-	-	-	-	-	-	-	-	-	0.25	-
Coleoptera												
Dytiscidae	-	-	-	-	-	-	-	-	0.25	-	-	-
Hydrophilidae	-	-	-	-	-	-	-	0.25	-	-	-	-
Hydraenidae	-	-	-	-	-	0.50	-	-	-	-	-	-
Mean Number of Organisms	1.50	1.50	1.25	2.00	0.25	1.25	0.75	1.00	0.75	0	2.50	0.50
Grand Mean	-	1.40	-	-	-	-	-	1.00	-	-	-	-

TABLE F-10. MEAN NUMBER OF AQUATIC INVERTEBRATES COLLECTED IN SQUARE FOOT SURBER SAMPLES AT THOMPSON CREEK DURING 1975-1976. VALUES REPRESENT MEANS OF FOUR SAMPLES PER MONTH

	After Limited Remedial Treatment			During Remedial Treatment								
	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July
Annelida												
Oligochaeta	-	-	-	-	-	-	1.00	0.25	0.25	-	0.25	-
Arthropoda												
Cambarus bartonii	-	-	-	-	0.50	-	0.25	-	-	-	0.25	-
Insecta												
Plecoptera												
Peltoperla	-	-	-	-	-	-	-	-	-	-	-	1.50
Brachyptera	-	-	0.25	0.25	-	-	-	-	1.25	-	-	-
Leuctra	-	-	-	-	-	-	-	-	-	0.75	4.25	3.25
Acroneuria	-	-	0.50	0.25	-	-	-	-	-	-	-	-
Odonata	-	-	-	-	-	-	-	-	0.25	0.25	-	-
Boyeria	-	-	-	-	-	-	-	-	-	-	-	0.25
Aeshna	-	-	-	-	0.25	0.50	-	-	-	-	-	-
Cordulegaster	-	-	-	-	-	-	-	-	-	-	0.25	-
Anax	-	-	-	-	-	-	-	-	-	0.25	-	-
Hemiptera												
Corixidae												
Gerris	-	-	-	0.25	-	-	-	-	-	-	-	0.25
Rhagovelia	-	-	-	-	-	-	-	-	-	-	0.25	-
Megaloptera												
Sialis	-	-	0.25	1.00	0.50	0.50	2.00	0.75	-	-	0.75	0.75
Nigronia	-	-	-	-	-	0.25	-	0.25	-	-	0.25	0.75
Trichoptera												
Cheumatopsyche	-	-	0.25	-	-	-	-	-	-	-	-	-
Diplectrona	-	-	-	-	-	-	-	-	-	-	-	14.00
Polycentropus	-	-	0.25	0.75	-	0.25	0.25	-	-	0.25	-	-
Lepidostoma	-	-	-	-	-	-	-	-	-	-	0.25	-
Pycnopsyche	-	-	-	0.25	-	0.50	-	-	1.50	-	-	-
Diptera												
Chironomidae	-	-	-	1.75	0.25	1.00	0.25	0.75	1.75	-	9.00	14.25
Simulidae	-	-	-	-	-	-	-	-	-	0.25	-	-
Eriocera	-	-	-	-	-	-	0.25	-	-	0.25	-	-
Tabanidae	-	-	-	-	-	-	-	-	-	-	0.25	-
Empididae	-	-	-	-	-	-	-	-	-	-	1.25	-
Coleoptera	-	-	-	-	-	-	-	-	-	-		
Gyrinidae												
Gyrinus	-	-	-	-	-	-	-	-	-	-	-	0.50
Dytiscidae	-	-	-	0.25	-	-	-	-	0.50	-	0.75	-
Hydrophilidae	-	-	-	-	-	-	-	-	-	-	0.25	-
Mean Number of Organisms	No Samples		1.50	4.70	1.50	3.00	4.00	2.00	5.50	2.00	18.00	35.50
Grand Mean	-	1.50	-	-	-	-	-	8.50	-	-	-	-

TABLE F-11. COMPARISON OF BENTHIC INVERTEBRATES COLLECTED IN THOMPSON CREEK DURING MINING AND CONVENTIONAL RECLAMATION AND DURING REMEDIAL TREATMENT

Species List	During Mining & Conventional Reclamation*		During Remedial Treatment+	
	Percent Composition	Percentage of Monthly Occurrence	Percent Composition	Percentage of Monthly Occurrence
Annelida				
Oligochaeta	-	-	2.3	50
Arthropoda				
Cambarus bartonii	4.8	50	1.3	37
Insecta				
Plecoptera				
Peltoperla	3.6	50	2.0	12
Brachyptera	-	-	2.0	25
Leuctra	32.7	80	11.0	37
Acroneuria	1.2	10	0.3	12
Ephemeroptera				
Epeorus	0.4	10	-	-
Odonata				
Boyeria	-	-	0.3	12
Aeshna	-	-	1.0	25
Cordulegaster	-	-	0.3	12
Anax	-	-	0.3	12
Hemiptera				
Corixidae				
Gerris	2.0	10	0.7	25
Gyrinus	-	-	0.7	12
Rhagovelia	-	-	0.3	12
Megaloptera				
Sialis	14.9	50	8.3	87
Nigronia	7.2	70	2.0	50
Trichoptera				
Cheumatopsyche	21.0	90	-	-
Diplectrona	0.4	10	18.6	12
Polycentropus	4.4	20	2.0	50
Lepidostoma	-	-	0.3	12
Pycnopsyche	-	-	2.7	50
Diptera				
Chironomidae	6.8	50	38.5	100
Simulidae	-	-	0.3	12
Tabanidae	-	-	0.3	12
Hexatoma	0.4	10	-	-
Eriocera	-	-	0.7	25
Coleoptera				
Dytiscidae	-	-	2.0	37
Hydrophilidae	-	-	0.3	12
Empididae	-	-	1.7	12
Total Number of Taxa	13	-	26	-

*Qualitative samples collected by sweep net.

+Quantitative samples collected with surber samples.

TABLE F-12. COMPARISON OF PERCENTAGE COMPOSITION AND MONTHLY OCCURRENCE BENTHIC INVERTEBRATES COLLECTED AT OLLIS CREEK, STATION 3, DURING MINING AND CONVENTIONAL RECLAMATION AND DURING REMEDIAL TREATMENT

Species List	During Mining & Conventional Reclamation*		During Remedial Treatment+	
	Percent Composition	Percentage of Monthly Occurrence	Percent Composition	Percentage of Monthly Occurrence
Platyhelminthes				
Planariidae	-	-	14.0	50
Annelida				
Oligochaeta	-	-	3.2	25
Arthropoda				
Crustacea				
Hyalella	0.7	10	-	-
Lirceus	0.7	10	-	-
Cambarus bartonii				
Insecta				
Collembola				
Plecoptera				
Brachyptera				
Ephemeroptera				
Baetis				
Ephemera	2.8	20	-	-
Odonata				
Boyeria	-	-	1.1	12
Agrion	4.2	40	2.1	12
Argia	3.5	30	-	-
Ishnura	0.7	10	-	-
Ophiogomphus	0.7	10	-	-
Libellulidae	0.7	10	-	-
Hemiptera				
Gerris	0.7	10	-	-
Gyrinus	-	-	4.3	12
Veliidae	2.1	10	-	-
Megaloptera				
Sialis	0.7	10	2.1	25
Nigronia	2.8	30	-	-
Corydalus	4.2	30	-	-
Trichoptera				
Hydropsyche	51.8	60	18.3	62
Cheumatopsyche	11.3	50	1.1	12
Polycentropus	8.5	40	17.2	100
Pycnopsyche	-	-	2.1	25
Diptera	-	-	11.8	62
Chironomidae	3.5	30	-	-
Palpomyia	-	-	1.1	12
Eriocera	-	-	1.1	12
Tipula	-	-	20.4	75
Total Number of Taxa	17	-	14	-

*Qualitative samples collected by sweep net.

+Quantitative samples collected with surber samples.

APPENDIX G

(Supplemental information on fish)

TABLE G-1. FISH SPECIES COLLECTED FROM OLLIS CREEK AND ITS TRIBUTARIES DURING 1970-71 AND 1975-76

Common Name	1970-71	1975-76
Stoneroller	X	
Emerald shiner	X*	X
Minnow sp.	X**	
Creek chub	X	X
White sucker	X	X
Bluegill	X#	X
Least darter	X##	

* Identified as Notropis sp.

** Identified as Pimephales sp.

\# Identified as Lepomis sp.

This fish is not known to occur in the Clinch River drainage and probably represents a misidentification.

TABLE G-2. COMMON AND SCIENTIFIC NAMES OF FISH SPECIES REPORTED FROM OLLIS CREEK 1970-1971 AND COLLECTED FROM OLLIS CREEK AND NO BUSINESS CREEK 1975-1976

Scientific Name	Common Name
Campostoma anomalum (Rafinesque)	Stoneroller
Notropis atherinoides Rafinesque	Emerald shiner
Pimephales notatus (Rafinesque)	Bluntnose minnow
Rhinichthys atratulus (Hermann)	Blacknose dace
Semotilus atromaculatus (Mitchill)	Creek chub
Catostomus commersoni (Lacepede)	White sucker
Hypentelium nigricans(Lesueur)	Northern hog sucker
Lepomis macrochirus Rafinesque	Bluegill
Etheostoma kennicotti (Putnam)	Stripetail darter
Etheostoma microperca Jordan and Gilbert *	Least darter
Etheostoma sagitta (Jordan and Swain)	Arrow darter

*This fish was reported from Ollis Creek in 1970-1971. It is not known to occur in the drainage and possibly represents a misidentification of E. flabellare.

APPENDIX H

(Supplemental information on comparisons of water quality and invertebrate data in affected streams with that of a reference stream)

TABLE H-1. COMPARISON OF WATER QUALITY PARAMETERS FROM STREAMS AFFECTED BY STRIP MINING ON A MINED WATERSHED (OLLIS CREEK) AND AN UNMINED WATERSHED (NO BUSINESS CREEK)

MINED WATERSHED					UNMINED WATERSHED				
Date	pH	Sulfate mg/l	Iron mg/l	Manganese mg/l	Date	pH	Sulfate mg/l	Iron mg/l	Manganese mg/l
- - - - - Ollis Creek Station 1 - - - - - -					- - - - No Business Station 1 - - - - - -				
01-21-76	5.4	-	-	-	01-21-76	6.3	4	0.08	0.01
02-18-76	5.4	60	0.78	1.4	02-18-76	5.8	6	0.56	0.03
03-16-76	5.2	57	0.28	1.2	03-16-76	6.2	6	0.19	0.01
04-07-76	5.2	43	0.43	.7	04-07-76	5.8	8	0.13	0.03
05-19-76	5.1	-	-	-	05-19-76	6.0	-	-	-
06-15-76	5.8	-	-	-	06-15-76	6.1	-	-	-
- - - - - Thompson Creek - - - - - -					- - - - No Business Station 2 - - - - - -				
02-18-76	4.3	100	1.4	2.4	02-18-76	5.8	5	-	-
03-16-76	4.8	65	3.2	1.6	03-16-76	6.2	6	0.10	0.01
04-07-76	4.5	69	2.8	1.7	04-07-76	6.0	6	-	-
05-17-76	4.7	-	-	-	05-19-76	6.0	6	-	-
06-15-76	4.5	-	-	-	06-15-76	6.2	-	-	-

TABLE H-2. COMPARISON OF BENTHIC FAUNAS COLLECTED IN SQUARE FOOT SURBER SAMPLES NOVEMBER 1975 TO JULY 1976 IN NO BUSINESS CREEK AND COMPARABLE OLLIS CREEK STATIONS

	Ollis Creek Station 1		No Business Creek Station 1		Ollis Creek Station 6		No Business Creek Station 2		Thompson Creek		No Business Creek Station 3	
	Total No.	Total* Biomass	Total No.	Total Biomass	Total No.	Total Biomass	Total No.	Total Biomass	Total No.	Total Biomass	Total No.	Total Biomass
Platyhelmenthes												
Planariidae	-	-	-	-	-	-	2	0.006	-	-	1	0.001
Nematoda	-	-	-	-	-	-	1	0.009	-	-	-	-
Nematomorpha	1	0.001	-	-	-	-	-	-	-	-	-	-
Annelida												
Oligochaeta	22	0.1203	57	0.4765	3	1.3279	11	0.0341	7	0.4638	15	0.1377
Arthropoda												
Ascellus	1	0.0057	-	-	-	-	-	-	-	-	-	-
Lirceus	-	-	509	1.6514	-	-	84	2.5023	-	-	122	0.3020
Cambarus bartonii	11	8.9952	8	12.5086	1	2.7148	32	22.3090	4	12.4123	22	9.8491
Insecta												
Collembola	-	-	-	-	-	-	-	-	-	-	1	0.0001
Plecoptera												
Peltoperla	-	-	34	0.5589	2	0.0214	20	0.1145	6	0.5017	73	0.7468
Nemoura	-	-	17	0.0229	-	-	17	0.0237	-	-	79	0.2926
Leuctra	2	0.0077	20	0.0173	12	0.0977	33	0.0641	33	0.5285	31	0.0188
Brachyptera	2	0.0027	4	0.0027	5	0.0806	2	0.0042	6	0.0018	3	0.0068
Taeniopteryx	-	-	-	-	-	-	-	-	-	-	1	0.0116
Isogenus	-	-	1	0.0118	-	-	3	0.0112	-	-	5	0.0084
Isoperla	-	-	13	0.0443	-	-	8	0.0326	-	-	15	0.0539
Chloroperlidae	-	-	-	-	-	-	-	-	-	-	-	-
Chloroperla	-	-	2	0.0067	-	-	4	0.0026	-	-	4	0.0599
Acroneuria	-	-	7	0.4327	1	0.0806	31	1.1787	2	0.2073	66	1.8688
Ephemeroptera												
Ephemera	-	-	1	0.0043	-	-	3	0.0343	-	-	3	0.0684
Stenonema	1	0.0179	85	1.8534	-	-	90	1.8477	-	-	60	1.3986
Epeorus	1	0.0121	52	1.2120	-	-	72	2.2051	-	-	12	0.5693
Heptagenia	-	-	-	-	-	-	4	0.0345	-	-	11	0.0795
Habroplebia	-	-	-	-	-	-	-	-	-	-	1	0.0078
Ephemerella	-	-	16	0.0885	-	-	8	0.0285	-	-	98	0.1720
Isonychia	-	-	-	-	-	-	2	0.0465	-	-	2	0.0274

TABLE H-2. (continued)

	Ollis Creek Station 1		No Business Creek Station 1		Ollis Creek Station 6		No Business Creek Station 2		Thompson Creek		No Business Creek Station 3	
	Total No.	Total* Biomass	Total No.	Total Biomass	Total No.	Total Biomass	Total No.	Total Biomass	Total No.	Total Biomass	Total No.	Total Biomass
Ameletus	-	-	-	-	-	-	8	0.2554	-	-	12	0.0116
Baetis	-	-	4	0.0114	-	-	17	0.0398	-	-	16	0.0267
Paraleptophlebia	-	-	5	0.0124	-	-	8	0.0402	-	-	13	0.0350
Odonata												
Gomphidae	-	-	3	0.0029	-	-	2	0.0023	-	-	-	-
Boyeria	-	-	-	-	-	-	-	-	1	3.1786	-	-
Aeshna	-	-	-	-	-	-	-	-	3	0.6603	-	-
Cordulegaster	-	-	-	-	-	-	-	-	1	0.0144	-	-
Anax	-	-	-	-	-	-	-	-	1	0.5741	-	-
Hemiptera												
Corixidae	-	-	-	-	-	-	-	-	1	0.1139	-	-
Gerris	2	0.0880	-	-	-	-	-	-	2	0.0392	1	0.0352
Microvelia	-	-	-	-	-	-	1	0.0032	-	-	-	-
Rhagovelia	-	-	-	-	-	-	-	-	1	0.0049	-	-
Megaloptera												
Chauliodes	-	-	-	-	-	-	1	0.4737	-	-	-	-
Sialis	1	0.0078	-	-	7	0.0238	1	0.0013	25	0.5262	-	-
Nigronia	3	0.4986	3	0.1559	4	1.1923	-	-	6	1.9179	2	0.4169
Trichoptera												
Rhyacophila	1	0.0185	6	0.0489	-	-	37	0.7743	-	-	23	0.3419
Glossosoma	-	-	15	0.0548	-	-	9	0.0357	-	-	22	0.0805
Cheumatopsyche	3	0.1674	15	0.0331	8	0.2071	34	0.1606	-	-	64	0.5584
Hydropsyche	29	0.9390	11	0.0620	4	0.3285	35	0.1510	-	-	50	0.1246
Diplectrona	-	-	3	0.0212	8	1.0825	8	0.0170	56	5.5395	13	0.1038
Dolophilus	-	-	2	0.0031	-	-	4	0.0365	-	-	1	0.0037
Chimarra	-	-	3	0.0051	-	-	2	0.0160	-	-	-	-
Sortosa	-	-	18	0.0169	-	-	68	0.2676	-	-	37	0.1672
Neureclipsis	-	-	-	-	-	-	-	-	-	-	2	0.0221
Polycentropus	1	0.0059	8	0.0149	-	-	11	0.0362	6	0.0195	15	0.1057
Brachycentrus	-	-	-	-	-	-	1	0.0079	-	-	-	-
Micrasema	-	-	-	-	-	-	-	-	-	-	1	0.0015
Goera	-	-	1	0.0190	-	-	-	-	-	-	-	-
Lepidostoma	-	-	6	0.0200	-	-	2	0.0093	1	0.0044	2	0.0085
Neophylax	-	-	-	-	-	-	-	-	-	-	4	0.1252
Pycnopsyche	-	-	1	0.0705	2	0.4131	22	1.9474	8	0.9590	8	0.1478

TABLE B-2. (continued)

	Ollie Creek Station 1		No Business Creek Station 1		Ollie Creek Station 6		No Business Creek Station 2		Thompson Creek		No Business Creek Station 3	
	Total No.	Total* Biomass	Total No.	Total Biomass	Total No.	Total Biomass	Total No.	Total Biomass	Total No.	Total Biomass	Total No.	Total Biomass
Diptera												
Chironomidae	28	0.0128	149	0.0881	53	0.2176	206	0.1750	116	0.1274	103	0.0422
Tipula	1	0.1472	19	5.1878	5	0.1865	20	7.6187	-	-	6	0.0809
Hexatoma	-	-	7	0.1430	-	-	10	0.0224	-	-	10	0.0920
Eriocera	-	-	59	0.3335	-	-	160	0.5597	2	0.0280	17	0.1629
Pedicia	2	0.0062	19	0.3818	-	-	1	0.0006	-	-	4	0.0516
Antocha	-	-	-	-	-	-	1	0.0037	-	-	2	0.0164
Dicranota	-	-	2	0.0063	-	-	4	0.0093	-	-	1	0.0139
Simulidae	3	0.0054	1	0.0009	-	-	5	0.0082	1	0.0019	3	0.0070
Simulium	24	0.1326	2	0.0004	-	-	1	0.0006	-	-	1	0.0002
Empididae	-	-	-	-	-	-	1	0.0005	5	0.3074	-	-
Tabanidae	-	-	-	-	-	-	-	-	1	0.0349	-	-
Atherix	-	-	1	0.0048	-	-	-	-	-	-	1	0.0097
Protoplasa fitchii	-	-	1	0.0240	-	-	-	-	-	-	3	0.0021
Heleidae	2	0.0017	-	-	-	-	1	0.0032	-	-	1	0.0049
Palpomyia	-	-	-	-	2	0.0005	-	-	-	-	-	-
Coleoptera												
Psephenus	-	-	31	0.2146	-	-	8	0.0099	-	-	3	0.0386
Ectoparia	-	-	-	-	-	-	3	0.0038	-	-	7	0.0082
Dryopidae	-	-	-	-	1	0.0091	-	-	-	-	-	-
Dryops	-	-	9	0.0809	-	-	5	0.0236	-	-	3	1.4873
Staphylinidae	-	-	-	-	-	-	-	-	-	-	2	-
Elmidae	1	0.0352	4	0.0012	-	-	2	0.0069	-	-	7	0.0043
Hydroptilidae	-	-	-	-	-	-	1	0.0039	1	0.0112	-	-
Dytischidae	-	-	-	-	1	0.0953	-	-	6	0.0611	-	-
Gyrinidae												
Gyrinus	-	-	-	-	-	-	-	-	2	0.0079	-	-
Mollusca												
Spaeridae	-	0.0012	-	-	-	-	-	-	-	-	-	-
Total Mean per Sample	142	11.2071	932	25.9114	117	8.5200	1,126	42.6963	304	27.6171	1,095	20.0187

*Total biomass is expressed in grams.

APPENDIX I

(Supplemental information on fish biomass
in both the reference and affected streams)

TABLE I-1. NUMBERS AND WEIGHTS OF FISH COLLECTED BY ELECTROFISHING IN NO BUSINESS CREEK DURING 1975-1976

	Station 1							Station 2						Station 3					
	11/19/75	12/19/75	01/23/76	02/23/76	04/09/76	05/25/76	08/24/76	12/19/75	01/23/76	02/23/76	04/09/76	05/25/76	08/24/76	12/19/75	01/23/76	02/23/76	04/09/76	05/25/76	08/24/76
Northern hog sucker	1	–	–	–	–	–	–	–	–	–	–	–	–	16	–	–	–	–	–
Creek chub	11	12	15	20	6	7	3	9	6	28	–	NO	9	–	1	5	6	NO	3
Bluntnose minnow	4	–	–	1	–	–	–	2	6	1	–	–	–	–	–	–	–	–	–
Stoneroller	4	3	5	1	–	1	–	–	–	1	–	FISH	–	–	–	–	–	FISH	–
Blacknose dace	1	–	–	–	–	4	–	–	–	1	–		–	1	2	5	–		2
Arrow darter	1	–	2	1	–	3	–	–	1	–	3	–	–	–	2	–	–	–	–
Stripetail darter	–	–	–	–	–	–	1	–	–	–	–	–	3	–	–	2	–	–	1
Total wt. in grams	104.4	35	48	38	79	51	3	73	74	18	51	–	36	82	16	80	80	–	114

TABLE I-2. NUMBERS AND WEIGHTS OF FISH COLLECTED BY ELECTROFISHING IN OLLIS CREEK DURING 1975-1976

	Mile .78					Mile 1.3					Mile 3.37					Laurel Branch					Yellow Branch	Mile 4.15	Unnamed Tributary	Thompson Creek
	08/25/75	09/17/75	01/23/76	04/09/76	07/13/76	08/25/75	09/17/75	01/23/76	04/09/76	07/13/76	08/25/75	09/17/75	01/23/76	04/09/76	07/13/76	08/24/75	09/17/75	01/23/76	04/09/76	07/13/76				
Creek chub	9	11	-	1	NO	NO	NO	NO	NO	NO	9	1	NO	NO	NO	NO	1	2	-	NO	NO	NO	NO	NO
Emerald shiner																		1						
White sucker					FISH	FISH	FISH	FISH	FISH	FISH			FISH	FISH	FISH	FISH	-	5	13	FISH	FISH	FISH	FISH	FISH
Bluegill			2																					
Total wt. (gms)	47	53	3	4	-	-	-	-	-	-	47	2	-	-	-	-	4	52	68	-	-	-	-	-

TABLE I-3. FISH SPECIES COLLECTED DURING 1975-1976 IN OLLIS CREEK AND NO BUSINESS CREEK.

Common Name	Ollis Creek	No Business Creek
Stoneroller		X
Emerald shiner	X	
Bluntnose minnow		X
Blacknose dace		X
Creek chub	X	
White sucker	X	
Northern hog sucker		X
Bluegill	X	
Stripetail darter		X
Arrow darter		X

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(Please read Instructions on the reverse before completing)

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15. SUPPLEMENTARY NOTES

16. ABSTRACT

This study involves a selected watershed in which surface mining and unsuccessful reclamation efforts in the early 1970's resulted in adverse environmental impacts. Work on the east Tennessee problem mine seeks to correct reclamation deficiencies by applying land stabilization treatments and evaluating their effectiveness by measuring the degree of recovery of the affected terrestrial and aquatic ecoystems. Conditions documented during the mining and reclamation, and those existing prior to start of restorative treatments are recorded in this report to serve as baseline for measuring ecological recovery, which will be documented in a later report

17. KEY WORDS AND DOCUMENT ANALYSIS

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